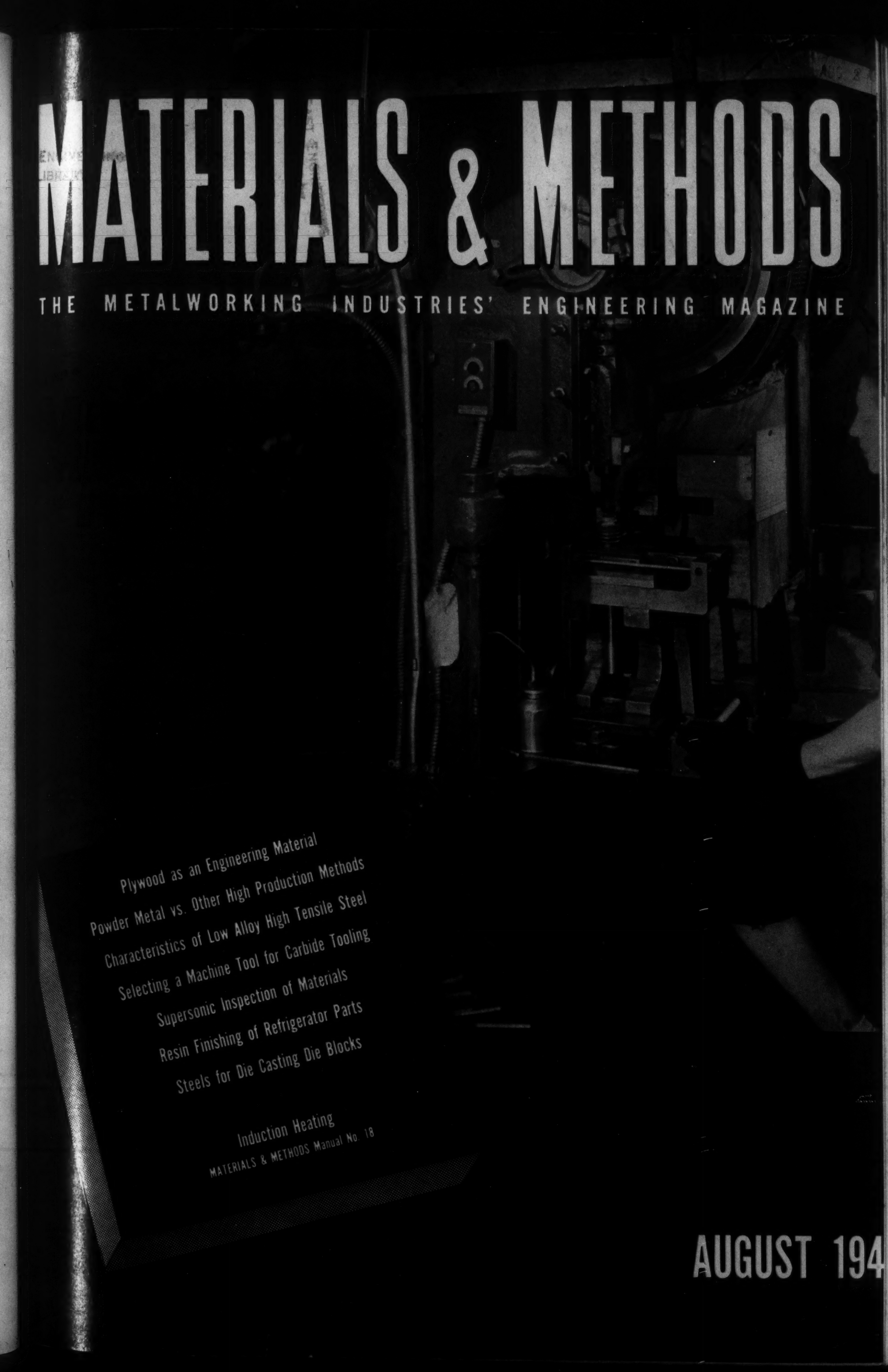
MATERIALS & METHODS

THE METALWORKING INDUSTRIES' ENGINEERING MAGAZINE

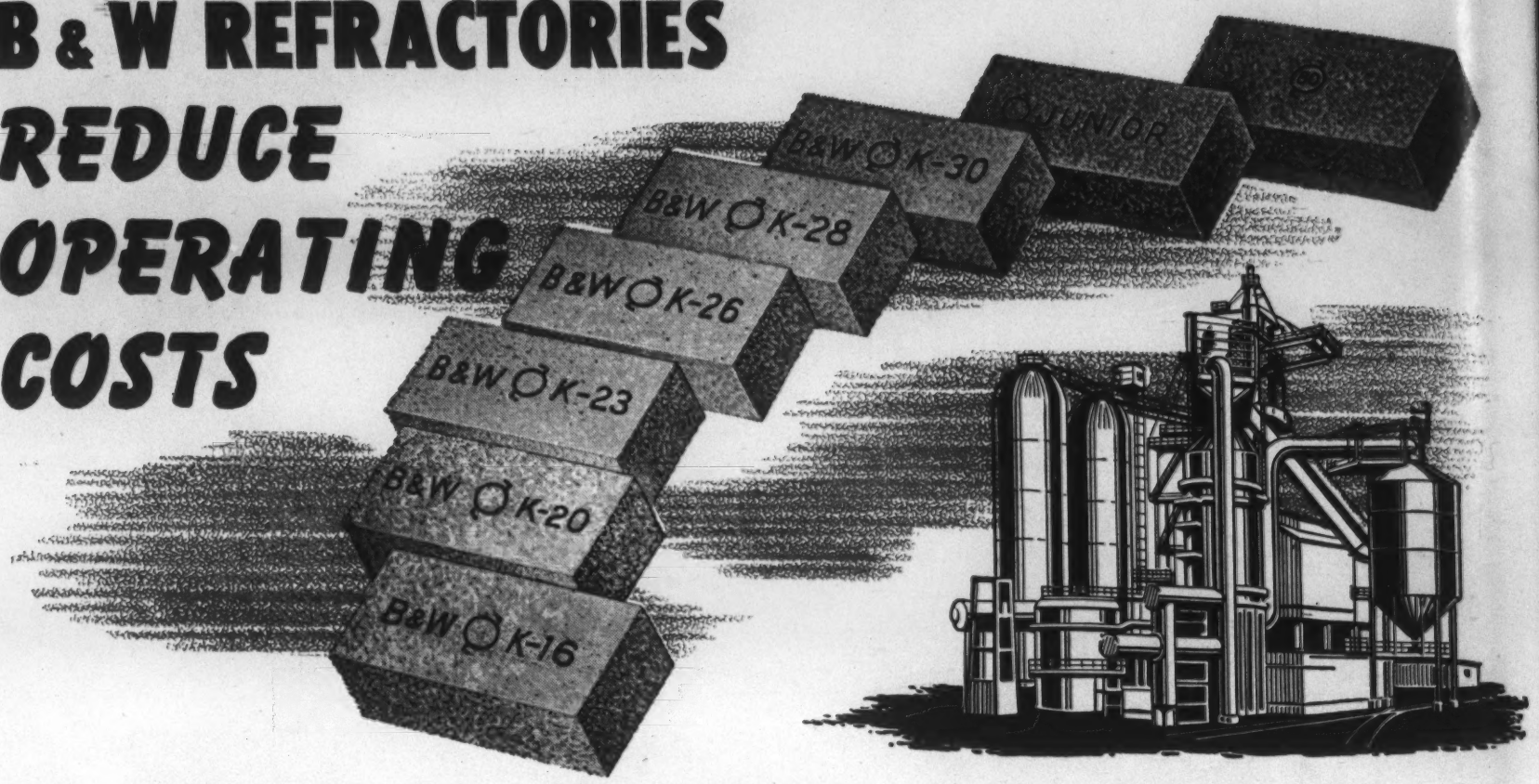


Plywood as an Engineering Material
Powder Metal vs. Other High Production Methods
Characteristics of Low Alloy High Tensile Steel
Selecting a Machine Tool for Carbide Tooling
Supersonic Inspection of Materials
Resin Finishing of Refrigerator Parts
Steels for Die Casting Die Blocks

Induction Heating
MATERIALS & METHODS Manual No. 18

AUGUST 194

B & W REFRACTORIES REDUCE OPERATING COSTS



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THE METALWORKING INDUSTRIES' ENGINEERING MAGAZINE

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This month's cover shows an unusual application of induction heating. The coil is mounted on the press and the pressing of one button energizes the coil and at the proper time causes the machine to function. (Courtesy: Induction Heating Corp.)

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Spectrography in a Magnesium Foundry
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Heat Treating with Lithium Atmospheres
Drop Forgings for Gas Turbine Applications
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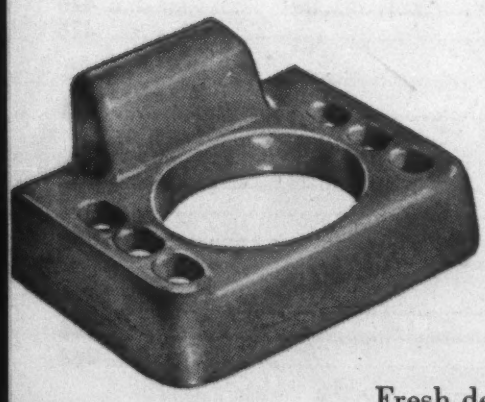
PLASTIC LAMINATES AS ENGINEERING MATERIALS
"Materials & Methods Manual" No. 19

RP REINHOLD

A material step toward home beauty



Fresh design! Enduring, living color! Styron blends these qualities with maximum effectiveness for home interiors—and gives maximum service, too! In bathroom fixtures, this Dow plastic permits design that makes for simple installation, ready removal and quick cleaning. Styron's lightness makes it easy to handle. Its smoothness and warmth give it a pleasant touch. And its solid dependability means extra life and satisfaction. Water won't harm Styron. Nor will alkalies from soaps, nor acids. You'll find that Styron serves long and well—and brilliantly! You can *depend* on Styron for permanent beauty and new design in satisfying products in the home.

Let's work it out together

Success in plastics is best measured in end products. It calls for combined efforts of manufacturers, designers, fabricators, raw material producers. Dow is ready to do its part. Save time and money—call on Dow and get the most out of plastics.

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PROPERTIES AND ADVANTAGES—Beautiful, clear, translucent; "pipes" light through rod around corners, etc.; resistant to acids and many alkalies; stable at low temperatures; excellent electrical properties; broad color range; low specific gravity, providing more moldings per pound; low water absorption.

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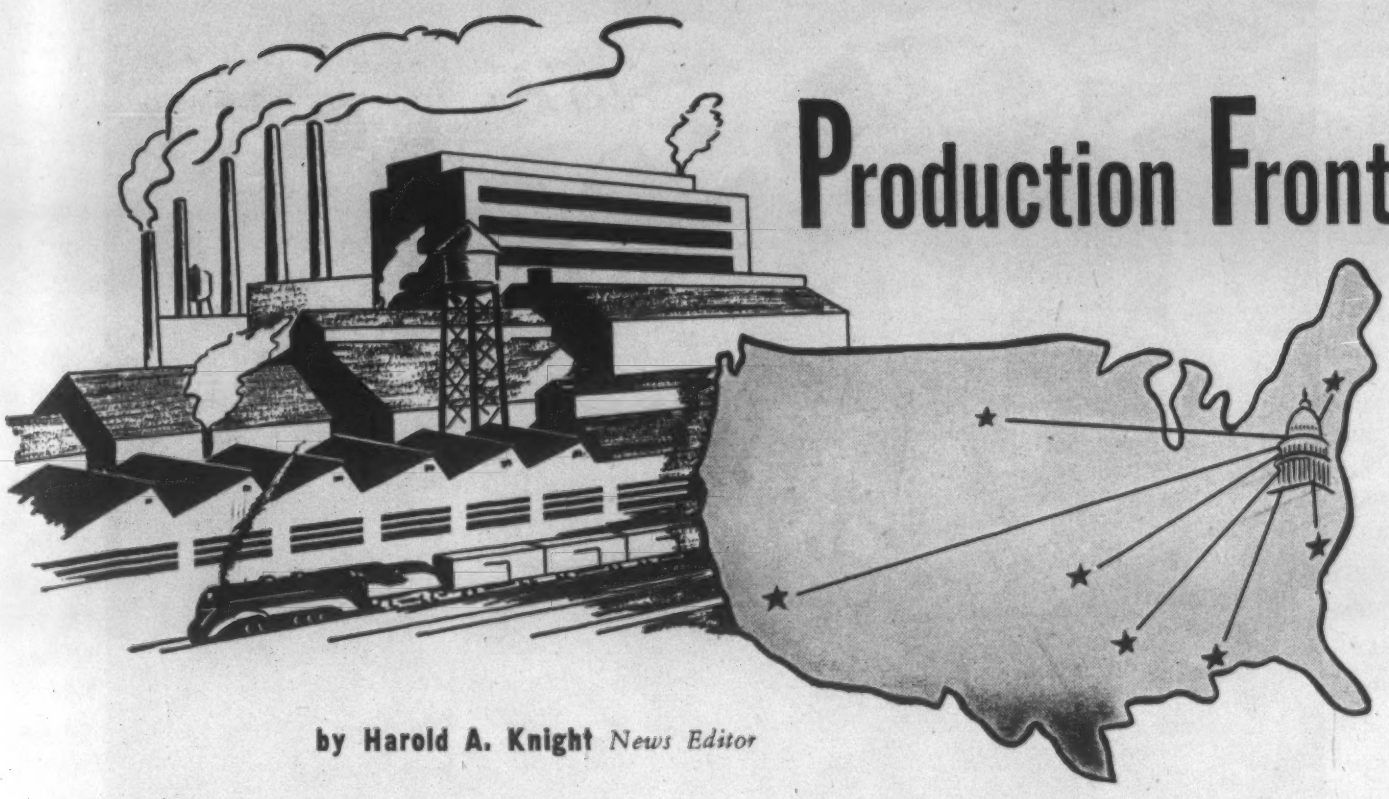


Production Frontiers

by **Harold A. Knight** *News Editor*

Even Labor Realizing That Production Is Panacea

A very attractive wife of one of the members of a British mission to this country to study our industrial methods sat in the front seat of an automobile with one of the officials of a large Detroit company. Realizing that the car interior was hot, he pushed open the cowl ventilator. A blast of air blew his companion's dress over her knees. She turned to him and said: "Heavens, don't you do anything by hand in the United States?"

Such was the anecdote told by Brig.-Gen. Donald Armstrong before the Magnesium Assn. We mention it merely as another illustration of the reputation our country has as a mass producer—with machines supplanting hand labor, with resulting stupendous production.

But alas! We have not been living up to that reputation. Thus, in the ten months from August, 1945 through May, 1946 production of ingots and steel for castings was 22,036,000 tons lower than for the same period of 1944-45. Strikes and work stoppages were largely responsible, states the American Iron & Steel Institute, which goes on to say:

Presumably, better operating conditions would have enabled at least 19,000,000 tons of that total to be made, which would have supplied the steel for 1,000,000 small dwellings plus the steel for 1,700,000 automobiles, plus all the bale ties made for farmers over the last nine years, plus 50 million one-quart tin cans, plus a washing machine and stove for each of the 1,000,000 homes—and still there would remain 7,500,000 tons of steel for other purposes.

Labor Leaders Not Oxford Gentlemen

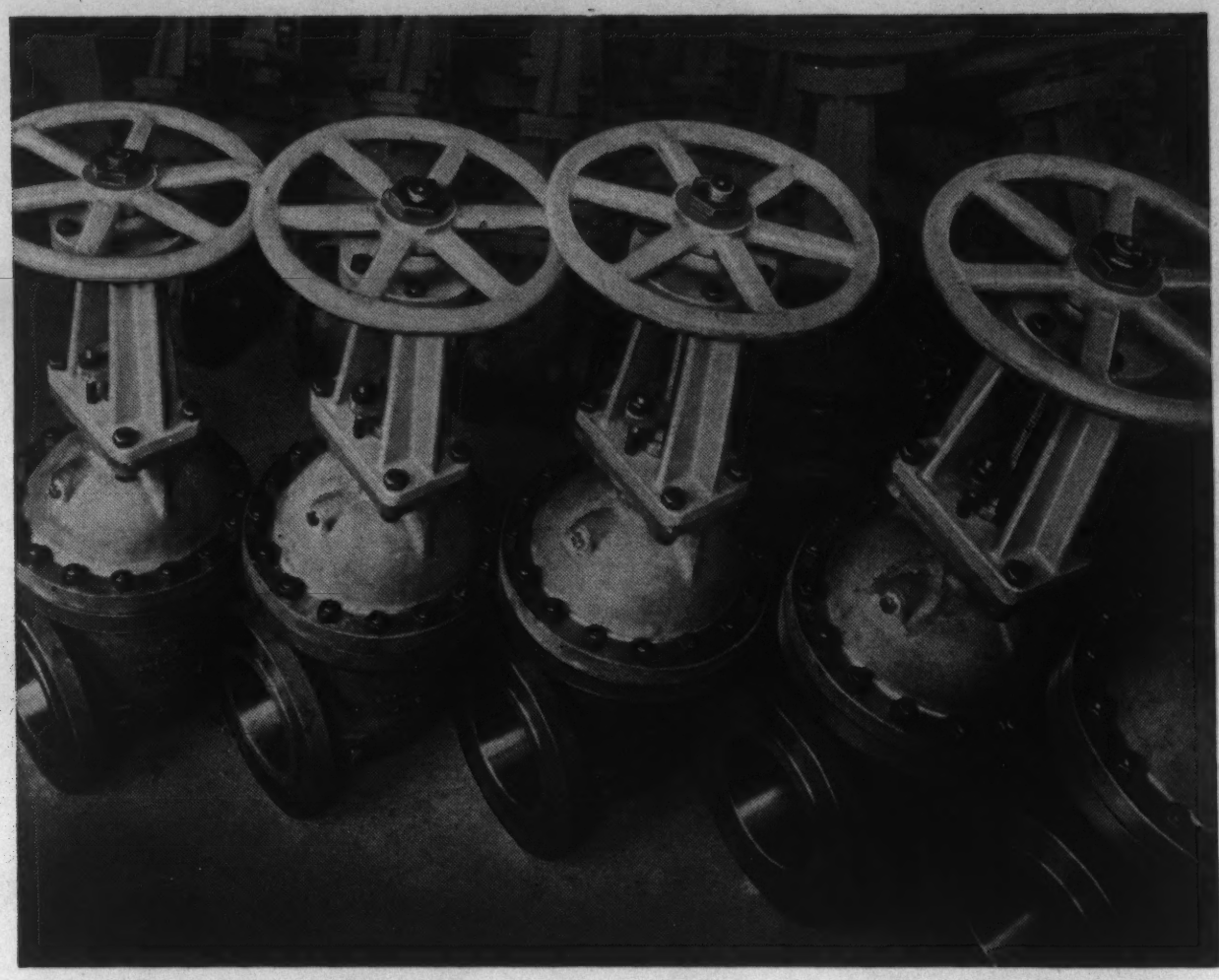
Meanwhile, talk against certain labor leaders becomes ever stronger. Here is the way the editors of *Army Ordnance* put it: "Recent irresponsible statements by various irresponsible labor leaders had very much in common. They were arrogant, vindictive, intemperate, and unfair. They were so packed with ideological cliches that they seem to have been copied from a Moscow primer on how to advance and promote the class struggle. We deplore the growing vulgarization and barbarization in public utterances, and we deeply regret that self-restraint, one of the marks of a gentleman, and one of the indispensable requisites of civilized living, should have been so grossly discarded by labor magpies who attempted to put the United States of America over a barrel."

Strong words, those! Meanwhile, the country has calmed down somewhat, and let's hope the era of paralyzing strikes is definitely over.

Sounding off on a key note in another quarter is J. K. B. Hare, Westinghouse official, who said in a formal speech: "Individual responsibility, resourcefulness and initiative have been undermined by years of propaganda supporting government responsibility for jobs; for maintaining purchasing power; for increasing farm prices; for 'holding the line' for all other prices; and for a Utopia of employment and permanent prosperity.

"There cannot be a sound economy in a state which tries to increase earning power by increasing purchasing power, as such," continued Mr. Hare. "Purchasing power that comes from earning power is always good; purchasing power that comes from any other source is suspect and usually fails in its purpose."

While speaking of the nations' productivity—or lack of it—we were



RESISTS ACID MINE WATERS

Stainless steel assures dependable service

These large valves, which are to be used for regulating the flow of acid mine waters, are made of stainless steel to resist corrosion. For their "tough jobs," many industries specify that valves be made of stainless steel because the resistance of the metal to wear and corrosion assures long and dependable service.

If you are interested in uses of stainless and other alloy steels, ask to receive our monthly publication, ELECTROMET REVIEW. If you need information on the production, properties, or fabrication of these steels, write our Technical Service Department. We do not make steel, but we do produce the ferro-alloys which are used in its manufacture, and our engineers have accumulated a fund of information on the use of stainless steel in many industries.

ELECTRO METALLURGICAL COMPANY
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STAINLESS STEEL

BEAUTIFUL ENDURING STRONG TOUGH

taken to task by a reader for a statement in our May issue that the normal bricklayer's stint is now 500 bricks daily as against over 1,000 bricks in 1931.

"Five hundred bricks," he remarks. "H—! Only 300 bricks is today's quota. And have you seen the modern hod carrier? It's a small container, hardly bigger than a berry basket and carries about four bricks! Wrap around with red and green ribbon and insert a sprig of holly and it would look like an X-mas present bought in the jewelry store!"

But let's get away from criticism and carping since recent months do not represent true America. Perhaps the most encouraging development was the recent exhortation from none other than William Green, president, A.F.L., who advised his 7,000,000 members that they could best stabilize their wage dollars by increasing production and thus eliminating shortages.

John L. Lewis, C.I.O. leaders, et al —please copy!

Russian Solar Energy Power

The Russians have built an apparatus that converts solar energy into steam sufficient for canning and chemical plant use, according to the American Russian Institute, New York. The solar heat boiler, with an estimated capacity of 120 klg. (260 lb.) of steam per hr., is mounted above a parabolic reflector about 33 ft. wide, which collects and concentrates the sun's rays. With it they have smelted metals, operated cocoon dryers and hot shower baths.

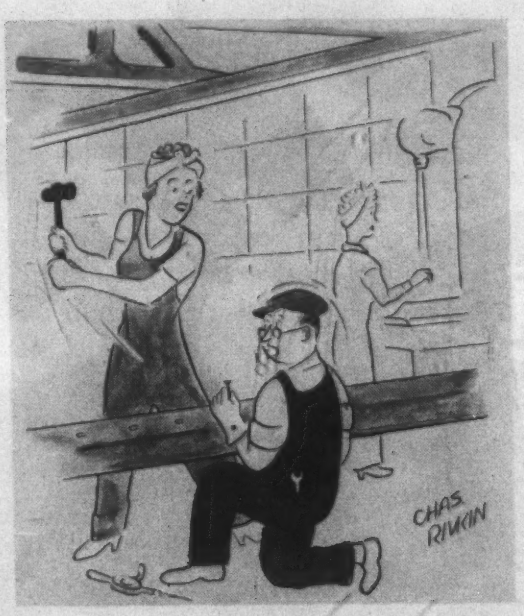
The Academy of Sciences of the U.S.S.R. has set up a commission to study industrial applications of sun power. Indeed, a solar radiation map of the entire Soviet Union has been prepared, giving charts and figures on the heat content of the sun's rays everywhere.

One of their most novel inventions is the solar refrigerator which maintains subzero temperatures when outside readings are 98 F in the shade. It consists of a solar boiler, combined with an absorption refrigerator which has no moving parts, except a small pump to keep the ammonia solution in circulation through a series of hermetically sealed condensing chambers. It can produce hot water and artificial ice at the same time, with great promise for the food industry.

How about solar machines in the backyard of the Los Angeles Chamber of Commerce, from which emanate reports of perpetual fair weather?

"Other Side of the River"

Scona Lodge is aptly named. "Scona" is Cherokee Indian for "other side of the river"—other side of the Little Tennessee River in this case. We and other technical editors spent some most enjoyable hours there recently as guests of the Aluminum Co. of America. Spent the late afternoons and evenings in this paradise in the Great Smoky Mountains, hot in the daytime but cooled by air rolling down the mountains in the evening.



Instructor: "When I nod my head, hit it real hard with your hammer." (Hospital Case History: B-439.)

Forenoons were devoted to learning industrial things. We inspected two of the Alcoa plants—the reduction plant and the sheet rolling mills —so vast that everybody rides down the aisles—bicycles, motorbikes and for us, midget automobiles. Great modern plants are these, turning out enough continuous sheets to stretch around the world.

The second day we visited four dams and power houses, three owned by the Aluminum Co., the fourth the Fontana dam and power house of the Tennessee Valley Authority. We were told that the government will actually spend less than its budget of 76 billion dollars on this enterprise! It's a grand spectacle worthy of a P. T. Barnum or more up-to-date Billy Rose. The Fontana power house, with its marble architecture, compares well with a most modern U. S. building at Washington. Its interior decorations are Dutch blue and Japanese red lacquer. Stretched over the entire length are the words: "1942. For the People of the United States. 1945." You threw out your chest a bit in pride of ownership.

But to get back to Scona Lodge—and you hated to leave in the first place—each room is furnished with two native woods, each pair being different. Decorative aluminum sheets line the shower bath; aluminum lighting fixtures were hammered out at the local high school; our genial host used an aluminum cigarette holder.

For vista one casts an eye over the 9-hole golf course stretching alongside the Little Tennessee River. At the pre-dinner refreshment hour one repaired to a little glen at the foot of the mountain similar to where Rip Van Winkle bowled in the Catskills. Farther up the mountain was a log cabin with pool table and other recreation equipment.

The darky servants were efficient and courteous, old time Southern style. Yes, suh! The Southern drawl of our hosts added to the languorous quality of the place.

Scona Lodge is a place of which dreams are made—and so far away from shortages, strikes, OPA uncertainties—and editorial work!

Little Group of Serious Thinkers

Our little group of serious thinkers from the office was donating its composite valuable thoughts at the luncheon table to the correct line of education for the younger engineer. It was discussing proposals—and perhaps even trends—to teach the young engineer fewer detailed techniques and more basic principles. Time formerly spent in mastering details could be devoted to the more broad arts and sciences, including history, languages and economics.

Then one of our group spoke up: "I went in for the broad stuff. I took Latin and Greek, for instance, but

Broadening the Field for Product Engineers

Sharon [illegible] assistance
the [illegible] Sharon
body [illegible] improving
[illegible]

SHARON STEEL CORPORATION
Sharon, Pennsylvania

the only good I can see visibly is ability to guess the meaning of certain strange words and do crossword puzzles. For instance, Hank recently spoke of a 'transducer' as the inspection part of a supersonic inspection instrument. Now 'trans' means 'across' and 'duce' to 'lead'—hence 'lead across' ".

"That's exactly what the transducer does", added Hank.

Whereupon Ted—he of the soaring imagination—volunteered: "Take Mussolini" ("No, you take him", chorused the serious thinkers).

"'Il' means bad", continued the imperturbable Ted. 'Duce' means 'lead'. Hence 'Mussolini—bad leader' ".

The little group of serious thinkers buried their mustaches into the foam on their beer.

Once Unwanted: Nickel

In a previous issue we discussed cobalt, which was once an unwanted metal because of the difficulty of separating it from silver. At one time nickel was another unwelcome metal, the Germans who discovered deposits in Saxony calling it "kupfernickel," or "copperdevil," because they really wanted the copper and the admixture of the whitish metal annoyed them no end.

This and other interesting anecdotes concerning nickel is told in *Steelways,* published by the American Iron & Steel Institute. The swordblades of ancient China and Persia became famous because of their strength, keenness and resistance to rust. They were made from meteorites which had fallen from the sky and were fused iron and nickel. Only recently have men learned to imitate and improve on this dramatic gift of nickel from heaven.

The Chinese were so eager to obtain nickel to mix with copper and zinc that they imported it from Litchfield County, Conn., even before the American Revolution. They made a metal compound which they called "paktong" and which they shipped to Europe where a Swedish scientist, Engstrom, finally succeeded in imitating it. The Germans, who had previously scorned nickel-bearing metals, now seized upon paktong and made a variety of utensils from it—hence "German silver," which was neither truly German nor silver.

Catch Phrase Artist—Our "Doc"

Little did our somewhat sedate E. F. Cone realize that he was coining an advertising slogan when he wrote an editorial for M & M within recent months on "Steel Is Still King." It was a timely editorial, what with many upstart materials and pretenders to the throne springing up in this allegedly great post war era.

But the U. S. Steel Corp. snapped up this title of "Doc" Cone's editorial and made it their advertising catch phrase, giving due credit to MATERIALS & METHODS.

So, Doc, we're beginning to suspect that you are an old hand at this advertising slogan business. Maybe you're the chap who originated "the beer that made Milwaukee famous," or "the skin you love to touch"—and named some of the perfumes, "Indiscreet," "Temptation" and "Night of Pleasure."

Come out from behind those false whiskers, Doc—we know you!

Stainless Steel in a Passenger Car

"Design Considerations for Railway Passenger Cars" is the title of an interesting booklet issued by Edward G. Budd as a tribute to the late Col. E. J. W. Ragsdale, designer of the first Budd stainless steel streamliner, who died the past winter. States Mr. Budd: "Colonel Ragsdale made himself an inspiration by his ability to look at each subject from a fresh angle. Even in death he still had on his countenance the intelligent, inquiring, quizzical look which I had been accustomed to for so many years."

"As for materials of construction, there is no unanimity of opinion or of practice. Low alloys of steel, aluminum alloys, and stainless steel are used," Col. Ragsdale told a group of automotive engineers. "The choice of material naturally influences design. Aluminum with its greater bulk and hence greater plate stability naturally favors a skin stressed structure. The low alloys of steel are mostly used in a skin stressed structure, too, but one in which the sheathing is frequently stabilized by attached stiffness. Stainless steel, with its much greater tensile strength, is best utilized in a truss system of side framing.

"Stainless has many advantages aside from corrosion resistance. Its use, however, involved a new philosophy of design. The problem is one of thinness and how to make it effective in compression or in panels. Very few members are ever in pure tension. A bicycle spoke is the only one I can think of at the moment, but we don't use these in car construction.

"With stainless steel, the roof becomes a principal structural member, not only when considering the car as a beam but also in end compressive loadings. It takes over one-third of the total bending movement of the car, and yet the metal used is the thinness of a calling card. It is a real compression member and so it should be. The roof has the greatest expanse of any member in the car. It is farthest removed from the neutral axis. We take a lesson from the paper box manufacturers and corrugate this thin sheathing fore and aft.

"Also, two heavy stringers run the full length of the roof from end collision post to end collision post to give end compressive strength four or five times required by the Railroad Assn. and act as efficient guard rails in case of an accident which might otherwise invade the roof. So the roof becomes the upper chord of the beam and is tied into the lower chord, which is the floor system, by the side frames.

"In the middle of the car the floor channels are welded to a center sill, the backbone of the car, which ties into the draft gear and couplers. The A.A.R. stipulates a minimum compressive value of 800,000 lb. Budd exceeds 2,000,000 lb., being able to do this with stainless steel with no increase in weight".

Col. Ragsdale gives other interesting facts about railroads. Of the totally loaded passenger car the body weighs one-third, the trucks one-third, and the equipment and passengers one-third. For every passenger the railroad carries a ton of equipment for service. "The railroad collects 2 cents per mile from you and donates 1 cent of it back to hauling the equipment which it supplies for your benefit". Railroads are 16 times as safe as air or highway travel. Railroad cars are built around the appointments. We do have to have windows where they belong according to the passengers and if the water cooler interferes with a structural member it is the structure and not the cooler which goes out. Railroads can offer a thoroughly relaxed travel, because of the feeling of being safe.

News of

Engineers — Companies — Societies

Engineers

Richard P. Seelig, for over 8 years with Powder Metallurgy Corp., Long Island City, has joined American Electro Metal Corp., Yonkers, N. Y., to do engineering and tooling for production work and engineering developments on new processes. He has written technical papers, largely on die design and pressing of powders.

Dr. John G. Thompson has become chief of the Metallurgy Div., National Bureau of Standards, having been chief of the Bureau's Chemical Metallurgy section since 1930 and assistant chief of the division which he now heads since 1942. He has studied uranium, aluminum and beryllium for airplane engines, "pure iron", refractories for high temperature metallurgical work, and effects of gasses in metals.

Benjamin F. Fairless, president of U. S. Steel Corp., has been awarded the Medal of Merit, highest civilian award, because of advice to the Chief of Ordnance on management, production and supply.

Marvin J. Udy, consulting engineer of Niagara Falls, N. Y., has left for Santiago, Chile to act as technical advisor for Fabrica Nacional de Carburo Y Metallurgia, a company that makes calcium carbide and ferro-alloys.

Dr. John Milton Blocker, Jr., physical chemist, has joined the division of nonferrous metallurgy, Battelle Memorial Institute. He has a degree of doctor of philosophy from Ohio State University.

John Douglas James has been made superintendent of the Grove City, Pa. foundry, Cooper-Bessemer Corp. Previous experience involved the Latrobe Electric Steel Co. and Erie City Iron Works.

William B. Keen has been made superintendent, farm equipment production, Graham-Paige Motors Corp. For 13 years he was in charge of materials for Dodge Div., Chrysler Corp., and for 17 years was factory manager of Fairbanks, Morse & Co.

W. Frank Kelly has become general superintendent of foundries, American Manganese Steel Div., with headquarters at Chicago Heights. He was formerly works manager of the Amsco plant in New Castle, Del.

J. M. Fenner has been made division superintendent, stainless steel, at the Waukegan, Ill. works, American Steel & Wire Co. *Ronald E. Griffiths* will succeed him as supervisor of the research laboratory in Cleveland.

Thomas G. Franzreb has joined the technical service division staff of Turco Products, Inc. While in the Navy he spent two years as materials laboratory officer in the Engineering Div., Jacksonville, Fla.

G. W. Shetler has become assistant superintendent, forge department, Barium Steel & Forge, Inc., Canton, Ohio, having been in the forging business for 26 years.

Clyde Williams, director, Battelle Memorial Institute, Columbus, Ohio, has been given the honorary degree of Doctor of Science by the University of Utah, of which he is an alumnus. Cited were his accomplishments in research administration and in directing the activities of the War Metallurgy Committee.

Companies

The *American Rolling Mill Co.* will spend $68,700,000 to the end of 1949 to expand manufacture of stainless steel sheets and aluminized steel; to install new soaking pits, coke ovens, merchant mills, etc.

Production by *Kaiser Aluminum* got under way early in July at the two Spokane plants of the *Permanente Metals Corp.* Included are a reduction plant and hot rolling facilities. The plants will make available 80,000,000 lb. of aluminum by years' end.

The tool and die division of *Lester Engineering Co.* has been reorganized as *Lester-Aetna Tool & Die Co.* and moved from Cleveland to Warren, Ohio. Facilities at the new location have been expanded considerably.

Executive offices of *Allegheny Ludlum Steel Corp.* have been returned from Brackenridge, Pa. to the Henry W. Oliver Bldg. at Pittsburgh. The company has licensed Darwins, Ltd., large British steel producer, for the manufacture of Allegheny Ludlum's new high temperature alloys.

The Government's aluminum extrusion plant at Phoenix, Ariz., has been leased to *Reynolds Metals Co.* for five years by the War Assets Administration, having been operated during the war by *Aluminum Co. of America.*

Follansbee Steel Corp. is leasing the steel production equipment and mill section of the *Parkersburg Steel Co.* plant at Parkersburg, W. Va., having an annual capacity of 36,000 tons of hot-rolled electrical sheets. Another change is that *Sheet Metal Specialty Co.* becomes the *Sheet Metal Specialty Div. of Follansbee.*

Elmer A. Schwartz, formerly of *Republic Steel Corp.,* has become president of *Portsmouth Steel Corp.,* which is acquiring the present Portsmouth, Ohio works of the *Wheeling Steel Corp.* He has been in the steel industry for 27 years.

The eastern office and warehouse of *Metallizing Co. of America* have been moved to 431 E. 75th St., New York 21.

An $80,000,000 corporation, to be known as the *Budd Co.,* will result from the merger of the *Edward G. Budd Mfg. Co.* and the *Budd Wheel Co.*

The *Indiana Steel Products Co.,* producer of permanent magnets, has acquired the plant of the *Cinaudagraph Corp.,* Stamford, Conn. The newly acquired plant will serve as a specialized division for production of many new magnetic materials developed recently.

The *Harvey Machine Co.* has opened a brass and aluminum extrusion division at Torrance, Calif., with five extrusion presses with capacity of over 1,500,000 lb. per month.

Societies

As of July 1, 86% of the exhibit space for the 28th annual *National Metal Congress and Exposition* has been sold, the five-day event to start Nov. 18, 1946 in the Atlantic City (N. J.) Municipal Auditorium. . . Formation of an investigation team to study German production and use of heat-resistant cerium alloys is announced by the *Technical Industrial Intelligence Branch, Department of Commerce.*

About 50 technical papers will be presented at the *Second National Electronics Conference* at the Edgewater Beach Hotel, Chicago, Oct. 3-5. There will be an exhibit of electronic equipment . . . Eugene W. O'Brien, vice president, W. R. C. Smith Publishing Co., Atlanta, Ga., has been nominated as next president of the *American Society of Mechanical Engineers* . . . John Imhoff, production manager, vacuum tube manufacture, General Electric X-Ray Corp., has become president, *Society for the Advancement of Management.*

Meetings and Expositions

AMERICAN CHEMICAL SOCIETY, semi-annual meeting. Chicago, Ill. September 9-13, 1946.

NATIONAL CHEMICAL EXPOSITION, Chicago, Ill. September 10-14, 1946.

SOCIETY OF AUTOMOTIVE ENGINEERS, national tractor meeting. Milwaukee, Wis. September 11-12, 1946.

AMERICAN INSTITUTE OF MINING & METALLURGICAL ENGINEERS, 75th anniversary meeting. New York, N. Y. September 16-18, 1946.

INSTRUMENT SOCIETY OF AMERICA, national instrumentation exhibit and conference. Pittsburgh, Pa. September 16-20, 1946.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, fall meeting. Boston, Mass. September 30-October 2, 1946.

AN EDITORIAL

Common Sense in Evaluating Materials

A week spent at the recent annual meeting of the A.S.T.M. was proof enough to us that significance is superseding tradition in establishing bases for rating materials for individual services.

Materials engineers everywhere are (1) attempting to exclude irrelevant physical properties as factors in materials-selection or design, even though the use of such properties (and the tests for them) may have been standard practice for the past 20 years; (2) carefully scrutinizing time-worn test methods, procedures and equipment to see how much of their hide is bound to 1935 ideas; and (3) increasingly using "simulated service" tests, especially on finished parts or product assemblies, rather than completely depending on standardized tensile or fatigue or impact tests made on bars of the raw material before processing or fabrication.

Some of the better-known "properties of materials" and their required tests that have been standard bases for materials-selection for years are now regarded with a cold and fishy eye by smart materials engineers and metallurgists. To these more enlightened brethren, for example, good ductility is considered a valid criterion of suitability-for-use only if it is actually required in the specified service to which the material is to be put. If the service involves no plastic deformation then a ductility requirement is irrelevant, and materials with something approaching zero elongation may, for entirely different reasons, be better for the particular service involved than those with 20% or 30% elongation. With this common-sense engineering philosophy some of our oldest prejudices about materials (e.g. against cast iron, just because it lacks ductility) are rapidly vanishing.

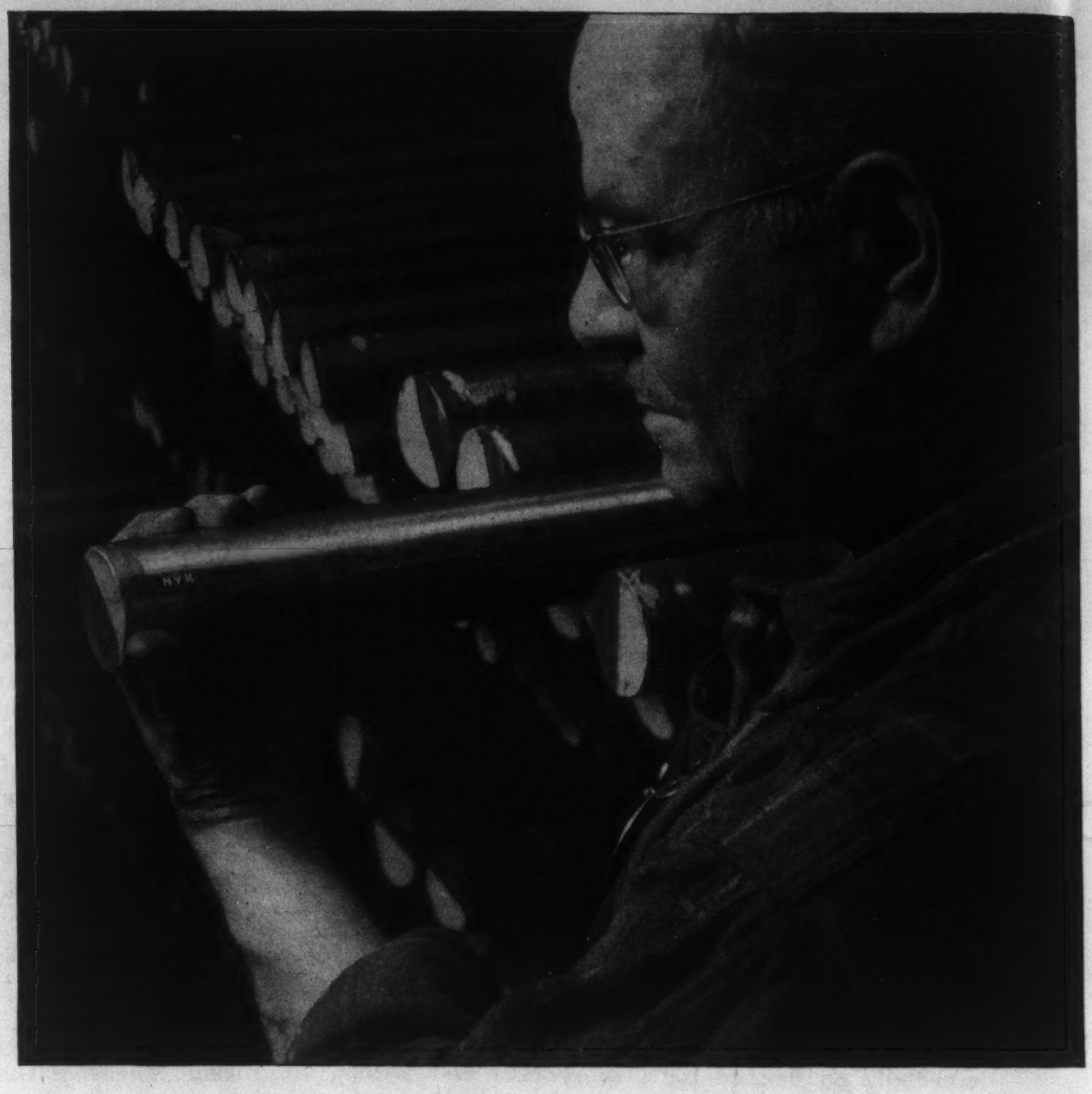
This policy of fitting the property-requirement to the actual needs of the service involved is similarly being applied to impact tests, salt spray corrosion tests and others, the *specialized* nature of whose applicability has not always been generally appreciated. The A.S.T.M. is now trying to establish the actual limits to which standard individual tests on single materials can be employed for service-life evaluation. Still more important is the Society's formation of an administrative committee on "simulated service" testing as applied to simple materials, composite materials and fabricated parts.

The prime mover behind this last development is the increasing number of "composite" materials (reinforced or laminated plastics, plated metals, metal-plywood sandwiches, etc.) and the lengthening list of fabricated forms (die castings, precision castings, powder metallurgy parts, impact extrusions, brazed assemblies, deep-drawn shapes, etc.) in which materials are now placed in service. After all, the material in the assembled product often behaves differently than it would before assembly or before processing.

This is not to say that the "fundamental" properties of materials are of declining interest to engineers, or that conventional, simple standard tests are on the way out. The standard tests for fundamental properties are essential to the intelligent development of new materials, for weeding out the completely unsuitable materials for specific uses, and for direct acceptance where positive correlation between tests and service has been established.

But there is a sharp and welcome trend toward using the simple, conventional standard test only *where it has significance* and developing simulated service tests for evaluating application-performance in those cases where several complicating service factors are involved.

FRED P. PETERS



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RYERSON STEEL

Editorial Comment

Men, Materials, Machines

All engineers are cost-minded. Engineering has been defined as the skill to do for ten cents what any damn fool can do for a dollar. The significance of recent changes in the industrial scene has not been lost upon them, and its reactions are already making themselves apparent.

A large part of the wage-earners in the mechanical industries have been given substantial increases in wage rates, and, as labor costs are an important part of fabricating costs, this means a substantial rise in total cost of the product. Almost immediately, the engineer is under pressure to make new savings, and so to attempt to hold prices in line. When ceiling prices were in effect this need was doubly necessary. Under any conditions most manufacturers want to hold necessary increases to the least amount.

The interplay of costs has been emphasized by results of the wage increases. With labor costing more, higher-cost materials that will require less labor in their fabrication have become practicable. Bigger investment in labor-saving machinery becomes a "must." Careful scrutinizing of plant processes for possible reduction or elimination of the increasingly expensive manual labor becomes one of the engineer's primary tasks.

It has been estimated that the raw materials in a plastic boat hull cost about twice as much as those in a plywood hull, and as against one of plank construction the differential is even greater. Yet plastic hulls can compete costwise with those of the cheaper materials because they are molded in a press, in one operation, and with a minimum of hand work. Ford Motor Co. has installed an almost manless machine set-up in one of its departments by a skillfully engineered combination of conveyors and automatic machinery. From all industry comes the demand for more elaborate multiple-purpose machines, with more automatic controls, and more automatic handling devices.

The events present a challenge and an opportunity to the machine tool industry, and to the materials engineers. Machine tool builders are being, and will continue to be, called upon as never before to supply ingenious labor-saving machines. For the materials engineer, there must come a complete resurveying of the whole field of materials in the light of the new cost relationships. The new machines will have electronic and mechanical controls to a new degree of elaborateness. A new balance must be achieved, and the engineer must achieve it.

—K. R.

Aluminum, or Equivalent, in Autos

When will the public be able to buy the much-predicted lighter automobile? Henry J. Kaiser recently stated that he had ridden in a car, of which 70% was aluminum. But we have our doubts at this date how general such a car will be. We recently received a letter from the chief engineer of a prominent automobile manufacturer. He said:

"We have been doing considerable experimental work with various materials, used in the war, but we have yet to find that any of the materials, particularly in the weight saving group, can be used to a sufficient advantage to justify their increased cost."

Even more specific was W. S. James, chief engineer, Studebaker Corp., in his testimony before the special committee of the Senate to survey problems of small business enterprises. Using the 1942 model of the Studebaker Champion as an illustration, a car weighing 3,200 lb., he stated that aluminum could be substituted in whole or in part for roughly 1,900 lb. He said that 1,100 lb. of aluminum would be required to replace those 1,900 lb. of steel, the overall weight of the Champion thereby being reduced to 2,400 lb. and at increased cost of $117.50.

However, aluminum is too expensive to cause those substitutions to be made, said Mr. James, who commented: "The automobile industry probably is the most highly competitive in America."

And then we thought of our own imperfect automobile which we have been forced to possess because of the war scarcity. We recalled the corroded muffler, the rusted steel frames of the windshield and windows, the rusted body where it joins the running board, the completely rusted steel channels which support the movable windows.

Mr. James, we would be willing to pay $117.50 more for an automobile if these vulnerable components were made of a more corrosion-resistant material, and we think there are thousands like us. But in your advertising and sales talk, Mr. James, you would have to drive these things home to the public.

We believe we're in a new era of appreciation on the part of the public of better materials. Some automobile maker will realize this, we believe—and soon.

—H. A. K.

Free Elections

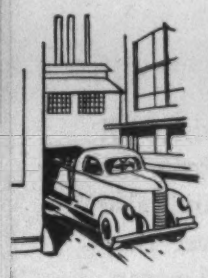
Since this is a democracy where all people are free and equal and have the right to speak their mind and also the right to vote for whomever they please, it seems that almost all organizations hold *free* elections of one kind or another.

The technical societies are no exception. All of you who are members of technical societies are acquainted with these *free* elections. You receive a ballot on which is listed *one* name for each office; and you are asked to vote for *one* man for each office. You, of course, in some cases have the privilege of writing-in, if you wish, the name of someone else for a particular office. But by-and-large the election systems used by technical societies are such that for all practical purposes the officers are elected by the nominating committee before the balloting of members takes place.

We have no quarrel with the nominating committee method of picking officers. It is probably the surest and most efficient system for selecting the best men to hold the key positions in technical societies. But we do object to the procedure from there on. Since the nominating committees now have, in reality, the entire responsibility and function of both nominating and electing the officers, why pretend to have a *free* election. To our knowledge a nominating committee's choice of officers has never been questioned or voted down by the members of a society. The balloting has become merely a perfunctory gesture. If the nominating committee procedure of electing officers is acceptable to a society, then why try to thinly disguise it as an honest-to-goodness free election. Receiving a ballot with no choice of candidates sometimes leaves members with the false impression that the election is rigged.

So, maybe the technical societies should ask themselves whether it's worth the effort and the expense to continue this one-party ballot system. Perhaps no great harm is done, but certainly there is no significant benefit derived from the procedure.

—H. R. C.



Special duty trucks gather steel samples for the laboratory.

A truck is unloaded at the laboratory, and immediately starts another round trip.

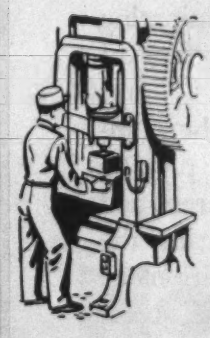
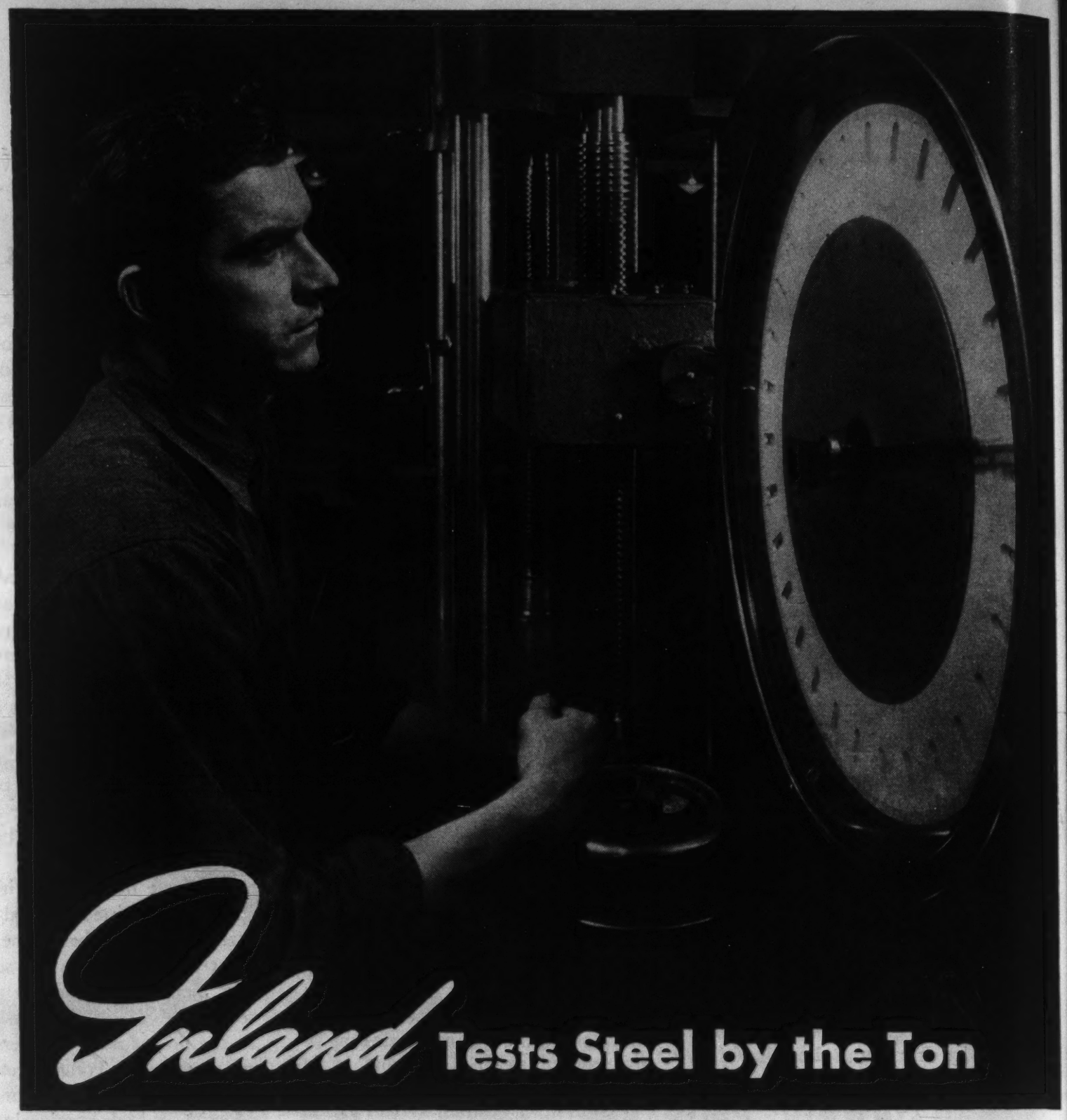


Plate samples are punched to rough form, then milled. Others are sawed, turned, drilled, etc., as required.



Operator determining physical properties on one of the many tensile testing machines in the Inland laboratory.

Many samples undergo rigid chemical tests.

Metallurgical tests are extremely important for quality control.

Darting from mill building to mill building—many times a day, and at night—are Inland trucks on special duty, a duty of vital interest to every user of Inland steel.

They are the sample trucks which rush samples of Inland products to the main laboratory where all required tests must be completed, reported and checked against specifications before steel is shipped.

Samples are gathered for the laboratory at semi-finishing mills—pieces from billets, slabs, etc., that will be tested before the steel is rolled into final form. Also collected are samples of finished products. Depending upon requirements, every piece of steel delivered to the Inland laboratory undergoes rigid physical, chemical, and metallurgical tests. Many of these tests are special developments by Inland—tests that are fast and extremely accurate.

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MATERIALS & METHODS

THE METALWORKING INDUSTRIES' ENGINEERING MAGAZINE

Synthetic-resin bonded plywood, after having been molded to shape, i ready for application as the transom of a modern power boat in the pla of Ventnor Boat Co., Atlantic City. (Courtesy: American Cyanamid Corp

Plywood as an Engineering Material

by EDWIN LAIRD CADY

PLYWOOD AS AN ENGINEERING MATERIAL existed in the days of the Pharaohs who, as far back as 1500 B.C., made coffins and furniture of it. Yet, in some of its latest constructions and forms, it might easily win a contest as "the material most likely to be improved throughout the next ten years".

A wide variety of industries are interested in finding more use for plywood, expanding the present uses, increasing its strengths and other qualities, developing and producing more kinds. The U. S. Forest Products Laboratories and other government agencies see in it a means of adding to the income of the farmer by increasing the sale of his wood lot products. Lumber companies know that turning logs into veneers and then laminating them into plywood can make 85% of a log useful for purposes which formerly would consume only 20%. The government and the companies alike glance at our dwindling lumber supply, see conservation by turning fewer trees into more lumber and more dollars.

Glue makers find plywood to be the biggest bulk market they ever enjoyed. Resin makers are producing adhesives for it too; in some instances their applications go so far that it is hard to tell whether the final product is wood laminations fastened together by plastics or plastics reinforced by veneers.

Rollers of thin sheet metals vastly expand their markets by glueing their sheets to plywood bases which supply high stiffness with low weight. Makers of glass, textiles, papers and other surfacing materials also are using plywood bases.

Machinery makers are developing special molding

Certain plywoods, study has shown are unaffected by shock, vibration and other stresses and are able to withstand severe weather conditions.

Many plywoods are supplied to the ultimate user in the shape of preforms such as this small boat hull. (Courtesy: U. S. Plywood Corp.)

presses and other fabrication equipment. Cutting equipment makers are busy too; not only are fabricating speeds and economies highly important, but some plastic impregnated plywoods will dull cutting tools faster than will mild steels. The makers of radio frequency electric heating equipment are finding the dielectric heating of plywood for glueing and for molding so good a market that some of them are neglecting the induction heating of metals in order to devote their engineering staffs to plywood and to plastics developments.

Hard on the heels of all these developers are the industrial consumers. Makers of railroad cars, ships and boats, prefabricated houses, furniture, and almost everything which requires broad surfaces with stiffness, strength and light weight, all are asking for more plywood and more kinds of plywood. The automobile and airplane markets alone could keep a large plywood producing industry going full blast.

Much was not known about the endurance of some of the latest plywoods until Mosquito Bombers and other plywood war equipment could be demolished and dissected for testing. It was found that the plywoods had been unaffected by the severe shock loads, vibrations and other stresses and by the exposure to fungus, rot and all kinds of weather incident to war service. The plywoods used included many which never had been made before the war.

Some of the newest glueing techniques came into production line use only in 1945. Veneer lathes of precisions comparable to those of the best metal working machine tools are coming into wider use and will improve plywood qualities; the strength of the bond between veneers (glue line strength) is highly dependent upon the accuracies with which the veneer surfaces are finished. Techniques for seasoning the veneers to exact moisture contents before glueing have been improved.

Many Factors Affect Properties

Plywood comes in many forms and constructions, some of which are patented. Factors which may be varied to obtain different specific properties include:

The kind of wood or the combinations of woods used.

The thickness of each ply. Some plies may be thicker than others, even to the point where the material becomes a "sandwich" of two thin plies surfacing one thick one, or two thick ones with one thin one between them, etc., or more usually all plies may be of equal thicknesses.

The directions of grain. Usually the grain of each ply crosses that of its adjacent ones at a 90-deg. angle, but this angle may be reduced to 45 or some other number of degrees, or all grains may be parallel, or 8 plies have their grains parallel while the middle or 9th. one runs at right angle to the others, etc. When the alternating grains are at right angles the directional strength is equal lengthwise and crosswise if the number of plies is even, and the directional strength is greater in the direction of the grains of the larger number of plies if the number of plies is odd, all other factors being equal. Other combinations of directional strengths similarly are obtained by combinations of grain directions.

The amount of pressure applied to the wood. The more that wood is compressed the more it gains in strength but also in weight for volume.

The preparation of the veneer. For best results, moisture content must be closely controlled. Highly accurately planed surfaces form stronger glue lines than do those subjected to sanding or other "scuffing up" processes to obtain accuracy.

The kind or kinds of glue used. Glues determine very largely whether plywood is resistant to dampness, water, fungus, rot, boiling, dry heat, alcohol, and other enemies. Glues affect the ability of the plywood to be preformed or molded to shape while being made, postformed or bent to shape after being made, secondary glued or assembled with other plywood pieces or other materials by glueing, repaired by cutting out broken places and applying glued patches and braces. Glues strongly affect the machineability and other fabricate-abilities of plywoods. To obtain combinations of properties some plywoods have different glues between different laminations.

Glueing methods and techniques. Some of the

most commonly used glues are fool proof. They may not make the full strengths of the wood fibers useful for load bearing, but they can be kept mixed for long periods of time and can successfully be applied to poorly finished surfaces with very little control of heat and pressure. Other glues, especially some of the lately developed ones, can contribute much more to the strength and other qualities of the finished plywood but they must be mixed in smaller quantities because they set if allowed to stand, the control of temperature and pressure must be highly exact when using them, and the quantities applied must be so balanced to the wood surface condition and the heat and pressure that the resulting glue lines are held within plus or minus 0.003 in. in thickness.

Some plywoods are intended for only short service lives in non-returnable shipping cases and the like. For these, glues which have only reasonable service lives may be used. Other plywoods are intended to be nailed to flat surfaces and be used as panels only. These bear no loads and in them glues which will weaken over a period of years but are not likely to come unstuck may be used.

When the plywood is intended to be load bearing, as in some of the modern skin stressed wall structures and in most applications to railway and airplane and automobile devices, then the glueing must be both strong and permanent.

There are, then, hundreds of possible combinations of the materials and methods by which special qualities can be given to plywoods.

There also are hundreds of plywood makers. The largest of these make their own veneers although very few make their own glues. The smaller ones buy their veneers and glues, do their own applying and pressing. Many who need special shapes, special combinations of veneers and glues, find it economical to assemble their own plywoods on special equipment which is suitable for their own products alone.

As with any other material of industry the standard grades and brands of plywood are to be preferred where they can be used with economy. Special qualities cost more. But producers can be found to make anything from ordinarily good plywoods which are put together with fairly good veneers and fool proof glues, up through the gradients of quality to the very most special. For making anything other than the qualities and specifications ordinarily running through his mill the average plywood maker wants a minimum order of one car load, and a carload holds 75,000 sq. ft. of ⅛-in. thickness plywood or an equivalent amount of any other thickness.

Standard sheet sizes run up to 8 ft. long by 4 ft. wide. Larger sheets can be made on special order, or can be made by scarf joining several standard sheets, the only limitation on this last being the ability to transport the finished product to its destination.

Soft Plywoods Most Common

Softwoods, made of douglas fir and of pine, are the most common plywoods. In a good peace time year the nation's mills could turn out close to two billion square feet by three eighths inches thick of these. Most of the softwoods are made to U. S. Government Commercial Standard CS45-42 and are completely standardized. Water proof grades are made for building exteriors, for marine use, for concrete forms, and other uses.

Hardwoods are made largely of gums but also are faced or are made throughout with other hardwoods. They are stronger, more wear resistant, more ornamental than the softwoods. Most of them conform to U. S. Government Standard CS35-42. About one-third as many square feet of them are made as of the softwoods.

All other plywoods are called technical grades. They make up only a small percentage of the total output of the industry but they are of high interest to the engineer. They include compregs in which the grains are parallel and are compressed into high but controlled strengths and resiliencies, impregs in which the veneers are so impregnated with plastics and then are so heated and pressed that all plies practically become a single solid mass, plywoods in which the veneer grains are not at right angles to each other, "sandwiches" with thick sheets between thin ones, other special combinations.

Contoured plywoods are rapidly advancing among the technical grades. They are to be had in standard shapes such as pipes and tubes which may be threaded or otherwise machined or may be glued together to form continuous sections. Most contoured shapes are preformed to special shapes, the contours being molded while glueing the veneers together.

As rules of thumb for plywood engineering, the strength of any piece of plywood is about three times that of an equal thickness of lumber of the same wood, and the stiffness of any plywood increases as the cube of its thickness. Additional stiffness and strength may be gained by contouring and by facing with metal. The available technical data on wood-glue strengths and on other plywood strength factors are not equal to those to be had on steels; scientific research along these lines is developing rapidly but has not reached its technical goals.

The engineeering uses of plywoods, especially of the technical grades, are increasing so rapidly that no one seems to have been able to list them all. A few of them:

Special returnable shipping containers for machine tools, machine assemblies, engines. Water and oil proof technical grades are usually selected, then are so built up of straight and of contoured sections that they supply unusually good bracing and shielding for all parts of the machines. They have saved as much as 500 lb. of shipping weight on machines to be exported. They can reduce the amount of "after arrival" assembling of mechanisms which, without such cases, would have to be shipped disassembled.

Skid boards and other surfaces which must be wear resistant but non-marring to metals and must have stipulated coefficients of friction. These usually are made of hardwood faced plywoods, or of metal faced plywoods. Many are so made and mounted that when

one face is worn the board may be turned and a fresh surface presented to wear. Some factory floors over which materials must be slid are being surfaced with these panels. Hardwood plywood is a preferred material for slider boards beneath conveyor belts.

Chambers for cold storage. The plywood is a good insulator, an excellent ally of cork, rock wool, foil and other insulations. As has been discovered in airplane use the plywood is less subject to frosting and to "icing up" than are some other materials. Plywood slotted bins which are strong but have openings to permit cold air circulation, also are widely used in cold storage rooms.

Tanks, bins and silos for wet or dry materials handling. These are readily fabricated from standard plywood sheets, or may have preformed parts. They can be made weather proof, and proof against most materials which are to be stored and handled. Like many other plywood structures, some of these are made demountable so they can be readily disassembled and transported along aisles between production machines and set up in new locations.

Easy Fabrication Desirable

Chambers for drying, for vermin control, and for processing. Low heat transmission, low abrasiveness to the materials being processed, and ready fabrication into the desired sizes and shapes, are some of the desirable plywood qualities. Dehydration experimental chambers often are made of plywood.

Demountable masts and other tall or long hollow structures. Originally developed for radio masts in war time these preformed technical plywoods are fabricated into shipping containers and are used in materials handling installations where height with light weight are wanted.

Assembly boards and tool boards. Some of these are preformed and contoured to fit the parts which they are to hold, but most of them are readily contour sawed from standard plywood panels and then are glued or nailed together.

Casings for process drying and for protection. Many of these are made demountable or semi-demountable assemblies of plywood staves or contoured plywood parts fastened together with steel bands and clamps. In some instances the casings are assembled like barrels or casks, the product to be dried or processed is packed into them, and after the process has proceeded through its first stages the casing may be removed for inspecting the product and then may be reassembled about the partly solidified product for its further processing and protection. Many others are demountable to permit maintenance cleaning and other operations on the parts being protected.

Machinery housings. These usually are specially contoured and preformed, although many can be made by sawing standard sheets into shapes and assembling by glueing. They usually are made of oil proof technical grades, and some have glass panels set in for observation. They are an inexpensive way of achieving machine protection and operator safety, and of eliminating oil splashing and oil fog hazards.

Hammer boards for drop hammers. Originally these were made of heavy boards of the hardest maple. Now they are laminated from lower grades but with wear resistant facings of closely controlled coefficients of friction.

Parts which have to stand severe concussion, such as textile shuttles and some of the chemicals mixing paddles, are being made of the modern plywoods with superior results.

To these products may be added parts of diesel engine cabs, truck bodies, escalator sides, tool stands, freight car interiors, elevators, prefabricated houses, airplanes, box girders, laminated joists.

The softwood plywood story is an old one although some phases of this industry were vastly improved during the war. Hardwood veneers, in plywoods or on common wood bases, also are old although new types and uses were found during the war. But the technical plywoods, volume-wise the smallest part of the plywood industry, are due to be developed in hundreds of new types and to find thousands of new uses.

In the manufacture of southern plywoods, large logs are turned in lathes and veneers peeled to the desired weight and thickness. This scene is in the plant of Darlington Veneer Co. (Courtesy: American Cyanamid Corp.)

When selecting a method for the production of small parts, there are some factors which point to one way as a "natural" or to its elimination.

These are believed to be the largest and smallest parts produced to from sintered powder metal (by Chrysler's Amplex Div.). The size of the la part can be judged by that of the cigarette lighter at right. The sm parts (lower left) are rivets about 0.054-in. in dia. and 3/32-in.

Powdered Metal vs. Other High Production Methods

by HERBERT CHASE

IT IS EASY TO BECOME overly enthusiastic about the merits of almost any production method or of the product turned out by it. Usually, the enthusiast (perhaps often unconsciously) harps on the merits of his pet method or product and tends to minimize their shortcomings.

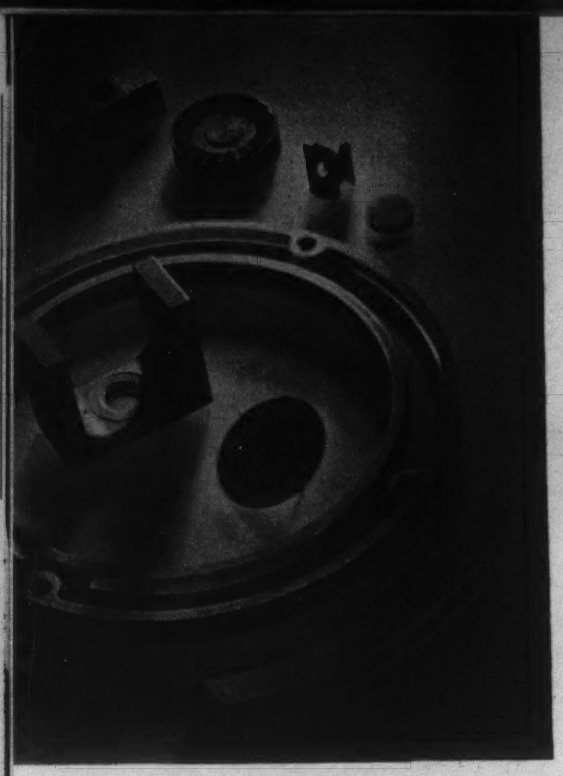
Sooner or later, however, the engineer and production man have to face and evaluate the economic facts, both favorable and unfavorable, if they are to arrive at logical conclusions. When concerned with quantity production, they usually have to determine how they can secure the most for each dollar expended. Competition forces them to do this.

For every established process there are types of parts that are "naturals," that is, parts so well adapted to the process that no other method can hope to compete. Some processes can turn out parts that cannot be duplicated at all by other means. Only parts sintered from powdered metal, for example, have controlled porosity. This is of special advantage where impregnation with oil affords a "self"-lubricating surface or where the sintered part is to serve as a filter. Powder compacts can be made also with certain combinations of metals or contain particular combinations of metallic and nonmetallic substances not readily combined by other means. Where these special conditions or compositions are essential, the makers of sintered powder compacts compete only among themselves, because such compacts yield advantages attained in no other way.

Then, too, there are frequent secondary operations to be considered, as few primary processes yield finished parts entirely ready for use. Often, details of construction that are possible when one process is used may have to be changed or sacrificed or require secondary operations if an alternative method is employed.

In view of these facts, it is not feasible to attempt to lay down any hard and fast rules to govern the choice of sintered powder compacts or of competing products. It is entirely feasible, however, to point out, under several headings, some of the factors that demand consideration in determining whether particular parts should be made from powdered metal or be produced by other means.

The processes that may compete and are taken into consideration here are: sand casting, die casting, stamping and screw machine production. Other processes that may deserve consideration in particular case include forging, plaster mold casting, permanent mold casting, lost-wax process and handling through machines other than the screw machines. To keep the discussion within bounds, however, detail comparisons with these latter processes are omitted.



Sintered powder metal compacts made by several different makers. The largest part is produced from aluminum powder and the others from copper, bronze and brass. Makers include Merriman Bros., Falcon Machine & Tool Co. and Amplex Div., Chrysler Corp.

Materials Available, Relative Costs and Properties

Theoretically, there are almost no limitations in the composition of powdered parts except that one or more components must be such that sintering or an equivalent binding of the powder particles is effected. Many combinations not feasible in other processes, such as "alloys" containing refractory metals of high melting point and mixes that include non-metallic materials, are attainable.

Actually, the primary materials used today in very large quantities are those composed largely of iron or steel, sometimes with nonferrous additions, and bronzes having about 90% copper and 10% tin, sometimes with minor additions. (As this discussion deals chiefly with metallic materials, reference to ceramics and to such materials as are largely graphite is omitted.) There are important uses of "special" mixes for such purposes as slugs, later drawn into filaments for lamps and for electronic applications; carbide tools and electrical contacts, but the tonnage of these is small and they are largely noncompetitive with other products here considered.

Parts sintered from powdered brass are coming into use and are thought by some to have a wide field of application still to be realized. Some aluminum alloys are offered. Magnetic parts are gaining extensive use and have properties unequaled except for some special sand cast materials. Some powder products employ plastic binders that insulate iron particles and impart useful magnetic properties. These have no parallel in products made by other methods dealt with here.

For stampings, the choice of materials is wide and includes almost any metal sheet or strip stock. But by far the largest proportion of stampings is made from mild steel, although the production from copper base and aluminum base sheet is extensive. Many stampings are produced from alloys not yet made on a significant scale, if at all, as sintered powder compacts.

Sand castings, though available in an almost unlimited range of alloys, have their largest output in iron and steel. Availability in brass, bronze, aluminum and other alloy is too well known to require comment. Some of these alloys duplicate the alloys made in sintered powder form but do not have the controlled porosity that is of special value in sintered compacts for bearings and for machine parts as can be adequately lubricated by oil absorbed in and fed from the pores.

Die casting alloys are all nonferrous and are based primarily on zinc, aluminum, copper and magnesium, respectively. Lead and tin alloys are also available but little used. None of present importance except brass and bronze (or possibly aluminum) have significant counterparts in sintered powder compacts but several doubtless could be duplicated, as to composition, in powder form if a demand and competitive factors warranted.

For screw machine work, almost any rod or tube that can be drawn or extruded can be used but free-cutting steels are most widely applied. There is also a large demand for brass and for aluminum alloys and even cast bars and tubes of bronze and of zinc alloy can be handled. Even extruded zinc and magnesium alloys are among those now available. Most materials turned into screw machine products could be duplicated as powder metal compacts but few such are in demand in that form. It is worth noting, however, that one maker of sintered powder compacts (Amplex Div., Chrysler Corp.) is now offering cored and bar stock in the form of such compacts. Such stock can be machined in the screw machine and in other cutting machines. It affords a means for making single or small quantities of parts from sintered powder without making compacting dies.

Most metals used in powdered form cost more per pound than for such corresponding metals as are available in cast and wrought forms, but this difference is sometimes offset by much less waste (see below) and by differences in density, the porous sintered powder part being somewhat lighter.

As to physical properties, space for only some very general camparisons is allowed here. The lower density as well as the grain structure of sintered powder metals is generally such as to adversely affect yield strength, ductility and impact strength, among other mechanical properties, as compared with those of corresponding wrought metals. In comparison with cast metals the differences may be less or even favor the sintered powder part.

Physical properties of sintered powder compacts depend considerably upon the pressure applied in compacting the powder and upon subsequent treatments. As with many other materials, the mechanical properties of test specimens may not be truly representative of those attained in sintered powder products. Data supplied by some of the largest makers of sintered powder parts are given in an accompanying table. Although higher values than these are attainable, those given are adequate for a wide range of applications. It is clear, however, that generally superior mechanical properties are commonly possessed by all comparable materials here considered as competing with sintered powder compacts.

Size and Weight Limitations

To date, the size and weight of parts produced from sintered powder metals has been limited, in

All of these parts, compacted from powdered metal, were made by McGuire Industries, mostly from iron, although three of the five smallest ones, including the two with ratchet teeth, are brass and the remaining two are in bronze. Four iron parts at top left have screw inserts and one includes a wire insert, all these having plastic binder and being used as magnetic cores. The flat parts in iron have a slot that is close to the edge, except for which they might be blanked from sheet.

general, to those of less than 8 sq. in. of area at right angles to the compression axis and about 3 in. in height. Chrysler's Amplex Div., however, points to the quantity production of parts weighing as much as 96 lb. and of parts as large as 20 in. in dia. It has made solid cylindrical blocks of about 12-in. dia. and 9 in. high. These very large sizes, however, require exceedingly heavy press equipment and the demand for such large parts is quite limited.

By far the largest output of and demand for sintered powder products is for those ranging from a fraction of an ounce to few ounces in weight. The average size may increase slowly as larger equipment becomes available but, as large presses require a large investment and are relatively slow in operation, there is considerable question whether economic considerations will permit their extensive application. No minimum size has been established but parts that run 100 or more per oz. have been made.

Compacting pressure commonly ranges from 15,000 to 25,000 p.s.i. minimum and sometimes runs from 50,000 to 100,000 p.s.i. but, as projected area increases, the size of presses needed may soon become prohibitive for any save exceptional demands.

Somewhat similar conditions apply in the case of die castings and stampings but, as the unit pressures required are much lower, the size of machines needed is correspondingly less. Stampings as large as turret tops for passenger cars, and end structures for freight cars are economically produced by stamping but the total number of presses used for such purposes is small. For stampings in smaller size, down to those of less than 1 sq. in. in area and fractional ounce weight, many thousands of presses are kept busy.

In die casting, pressures applied to the metal range usually from around 2,000 p.s.i. for zinc and lower melting alloys, 4,000 to 10,000 for aluminum and magnesium alloys and 9,000 to 25,000 for brass and bronze. Relatively few die castings of 2 sq. ft. projected area have been made and a maximum weight of around 35 lb. (with zinc alloy only) has been attained. But the average total die area is probably below 1 sq. ft. and commonly not more than one fourth of this area is subjected to injection pressure. The average projected area of the die casting is a few sq. in. There is no fixed minimum size.

For sand castings, made under gravity heads, although there are practical maximum size limits, these are so large that they need not be considered here. The minimum practical size is well below 1 oz. in most metals commonly sand cast. As with die casting, gates of many small castings are often produced, but the average size of sand castings is probably larger than for die castings.

Automatic screw machines for making parts up to 8 in. dia. x 8 in. long (in single-spindle types) have been built but relatively few for bars over 2½ in. dia. are in common use. Multiple-spindle machines for parts 5-in. in dia. and 20 in. long are available but the largest machines in extensive use can make parts 2⅝ in. in dia. x 6 in. long. A large proportion of products are below 1½-in. dia. down to parts running 100 or more to the ounce.

Since the large demand for all parts competing with those made from sintered powder metal is in the small- to medium-size range and larger sintered powder parts present economic handicaps, it is most unlikely that the average size of parts made from powder will show more than a slow increase.

Shape Limitations

Although a large range in the shape of sintered powder products has been made, there are some well defined limits on the shapes that are feasible. Both contours and internal shapes in planes at right angles to the pressing axis can be varied almost at will as long as the sections are not so thin that friction is excessive and the briquette too fragile to eject and handle. Through holes parallel to the axis are readily formed, if not so small that punches (cores) become too fragile. Blind holes are also feasible but with some limitations. No side holes or holes at odd angles can be formed with the types of equipment in general use and, when threads are required, they must be cut.

Variations in height (length, parallel to the axis) are permitted in any given piece but preferably should not exceed one-fourth the total length. Large variations in height tend to increase tooling cost and make pressing more difficult. Marked variations in section thickness may result in warpage during sintering. Sections thinner than 0.050-in. are rarely feasible and then only on small parts. No undercuts on either outer or inner surfaces can be produced in pressing, but they can be cut by machining after sintering. These limitations do not apply as a rule in the case of competing products but all such products do have certain limitations of their own.

Die castings can be cored at any angle and often have side projections or involve other external undercuts, cleared by using slides in the die. Undercuts in holes sometimes are possible, too, although they involve complications. Uniformity in section thickness is desirable but wide variations are quite common. Sections much thinner than for parts made from sintered metal powder are often die cast: 0.030 in. or less is not uncommon. External threads are often die cast and internal cast threads sometimes are feasible.

Sand castings can be made to substantially duplicate the shape of most parts made from powdered

metal except that holes less than ¼-in. dia., and not many even of this size, are commonly cored, at least in ferrous metals, and details are not so sharply defined. On the other hand, hollow parts, involving undercut cored holes or recesses are readily sand cast.

On the screw machine, it is possible to duplicate the shape of many parts now made from sintered metal powder but others, of irregular shape cannot be made completely if at all on the screw machine. The latter, in general, forms only surfaces of rotation although many machines have attachments for slotting, cutting flats and cross drilling. Holes made in the screw machine usually must be axial but can be undercut. External undercuts and threads, both internal and external, not possible except as secondary operations on parts made from sintered powder metal, are often cut on the screw machine.

These machines can use bars and tubes having hex or other shapes that remain on the finished part but holes must be round (unless broached in a secondary operation or in a tube initially). Holes with splines or keys, readily formable in sintered parts pressed from powder, require a supplementary operation on screw machine products.

Stampings that can be compared with parts made from metal powder are chiefly those that can be blanked from sheet or strip stock without much forming. Some drawn products and some that are coined in an operation performable in stamping presses are produced in shapes that can be compacted from powder and sintered. Many stamped parts cannot be reproduced as sintered powder metal compacts and many sintered powder parts are not reproducible by stamping.

Except for parts that must be porous, thin flat parts are nearly always blanked from sheet rather than formed from powder unless (1) holes are so shaped, so sized or so placed that they cannot be pierced or drilled with equal precision and economy; (2) piercing or blanking do not yield required surfaces; (3) some bosses or depressions not readily formed by stamping are specified or (4) blanking would involve excessive scrap loss.

Blanking and shearing tools often leave rough edges where the metal tears and drilling or shaving mean extra operations. In general, it is not feasible to pierce a hole smaller in diameter than metal thickness or to pierce holes close to an edge. These limitations do not apply at all, or at least to the same extent, in the part made from sintered metal powder and hence they give the latter chances that might not exist otherwise.

Rates of Production

Aside from making metal powders themselves, the production of sintered parts from powdered metal involves the following operations: (1) sifting and mixing the powder (2) filling the mold with powder (3) pressing or compacting the powder (4) ejecting the compact (5) sintering the compacts (6) (sometimes not needed) sizing, as by coining, the sintered product. Most of these operations are rapid but they require both labor and equipment. Operations 1 and 5 are done with bulk lots and the labor is not much of a factor.

Compacting is sometimes quite rapid, say 1 to 10 or more seconds per compact, for small to medium size parts. Sizing may take the same time, more or less. This does not allow for setting up the press. This may take up to 20 or more manhours, before production is achieved. Still, the labor per part is usually small and this is a great advantage favoring the use of sintered powder metal parts.

In die casting, melting of the alloy is often done at the machine. In large shops making their own alloys, some extra labor is required but is offset by economies. Casting rates range, as a rule, from about 100 to 1,000 die fillings an hour but, except for large castings, the die often yields a gate of two to a dozen or more castings (either duplicates or all different) per filling.

A helper usually breaks castings from the gate (which, including the sprue and runners, is remelted) and castings are later trimmed of flash, usually in shearing or shaving dies in a press. All these are rapid operations and labor per piece is low. Usually, some machining is needed on the casting. This is more or less equivalent to sizing of the powdered metal part and doing secondary operations, such as burr removal, on it, though often taking more time. The die casting, however, is often a much more complex part. Die setup usually takes ½ to 4 manhours.

For sand castings, aside from preparing the metal and melting it, it is necessary to make a separate mold (and often one or more dry sand cores) for each casting or gate of castings. Pouring, usually by hand, follows. When castings have frozen and cooled, the molds are broken up, sprues, risers and gates are cut off and sand cores are removed. Cleaning and machining usually require considerable time so that labor per cast is relatively high.

Stamping is a relatively fast process. Small parts are often blanked and sometimes are formed and drawn at the rate of several hundred a minute. With the progressive dies often used, a finished piece each second is not unusual. Presses often run automatically with almost no attention. As size increases, rates decrease but, in general, the process is the fastest of any here considered and as a rule less preparatory and subsequent work is needed. Sheets often have to be cut into strips and blanks and hand fed but frequently strip stock is fed automatically from rolls and flash is rolled up as formed.

Secondary operations include trimming, piercing side holes, shaving and the like, but these are rapid operations. In consequence, labor per piece probably averages lower than for any type of part here considered.

In the screw machine, nearly all operations involve cutting, often requiring considerable time but, as several operations usually are performed simultaneously and often at quite high speed, output is high, ranging, in general, from about 30 to as high as 3,600 pieces an hour. As the machines run with little or no attendance, except for supplying stock, labor charges are very low. Set up time usually ranges from 2½ to 8 manhours, and there is always

some down time for grinding and resetting tools.

Many products come from the screw machine in finished form but secondary operations on the back end of the piece such as cut-off, burring, cross drilling, tapping, slotting, milling flats, grinding or rolling threads are often needed. Some of these are done by attachments but secondary machines or rechucking are often needed.

One maker of parts in powdered metal states that, if yearly requirements are below 25,000, it is likely that some other method of production will be cheaper than to compact and sinter the part from powder. There may well be exceptions to this rule, but it is one that ought not to be overlooked.

Filter components made by compacting and sintering bronze powders of different degrees of fineness at Chrysler's Amplex Corp. plant. Comparable products can be made by no other method discussed in this article.

Tooling Costs

It is difficult to generalize profitably about tooling costs but some comments may prove helpful. Tooling for each type of product requires certain variations in methods, clearances and materials to secure best results or even to yield to a possible product. Those who develop the technique commonly regard the details as trade secrets and say little about them. This is true of powdered metal briquetting tools and of some tools used to coin or size the sintered compact.

As the making of compacting tools for metal powders is a comparatively new art, few die shops know what is required and die makers have to be trained for the job. Clearances often have to be held within a few tenths (of a thousandth of an inch) and surfaces exposed to the powder usually must be of extreme smoothness to avoid undue friction and to facilitate such flow of the powder as can be secured. These requirements are not easy to meet, especially on irregular shapes, hence die costs tend to run high.

One commentator says die costs range from about $150 for small simple parts to $1,800 or more for large parts and complicated shapes. It is not unlikely that this low as well as the high figure will be greatly exceeded in these days of high labor costs, especially for experienced toolmakers. Where all surfaces are those of rotation (which are simplest for grinding and much other machine work), costs can be minimized but this is true also in making dies for competing products.

As many if not most metal powders are abrasive, tool wear is likely to be rapid and tools may have to be replaced after making perhaps 10,000 to 20,000 or fewer compacts, depending in part upon the dimensional limits that must be held. For long runs, multiple tooling usually has to be figured. If the dial type of press that uses one or more sets of some male parts and a dozen or more dies is employed to achieve maximum compacting rates, die costs go up accordingly.

When the part is one that can be produced by stamping, especially by using blanking and piercing dies only, tooling costs are quite likely to be lower than for sintered powder parts. This is true when runs are not long, say below 10,000, but may apply also for much longer runs. If a shaving die and drilling are required, their cost has to be set off against such tools and secondary operations as may be needed on the sintered powder part.

There are today several methods of making blanking and even forming dies, especially for working soft steel and nonferrous sheet. Some such methods produce tools suited only for short runs but costs are then quite low and duplicate sets meet some needs when a single set might not do so.

Casting dies, especially for zinc and lower melting alloys, are quite moderate in cost. For aluminum and brass, somewhat higher die costs than for zinc alloys are entailed but even then the costs are commonly lower than for stamping dies of corresponding quality and for those for making powder metal compacts and for coining after sintering. This applies even where trim dies for removing flash from the die casting are included, as they commonly are in figuring tooling costs, except when only very short runs and hand trimming are contemplated.

For sand casting, tooling costs generally are said to be low but this depends in part upon what is included. When, as for most high production on small parts, metal patterns or match plates are required, their cost is not inconsiderable. Then too, there are commonly needed, in addition, some tools and fixtures for subsequent machining not required for the competing product. Frequently, the total is not far below or may even exceed the tooling for production by competing methods.

Screw machine tooling costs vary greatly with the shape of part to be turned out. Where the shape is simple, stock tools often suffice. In other cases, special form tools or box tools or cams may be needed and occasionally special collets or fixtures for unusual operations have to be made. If secondary operations are necessary, some special fixtures or chucks may be required. It is probable, however, that tooling cost averages lower than for any of the other processes here considered.

Scrap Losses

One of the marked advantages of working with metal powders is that the loss in scrap usually approximates zero unless the product has to be machined. Then the loss in chips must be debited. The usual coining or compressing operations that follow sintering waste no metal. They merely increase

Removing a powder metal compact from the die in which it was produced at Chrysler's Amplex Div.

slightly the density of the piece.

With stampings, scrap loss in flash is often considerable and sometimes exceeds the amount of metal in the product. Although such scrap has some sales value, as a rule, the cost of handling, baling and shipment for recovery reduces this value considerably, even when the plant has its own facilities for melting and reworking.

In the die casting process, sprues, runners, flash and chips are remelted and reused, often at the casting machine. In consequence, the scrap loss is slight (except in the case of magnesium alloys not in very extensive use), even though the remelt sometimes equals or exceeds the weight of the casting.

Somewhat the same is true in sand casting practice except that the scrap, including sprues, runners and risers, is collected and goes back to the cupola or smelting furnace. In any type of casting, remelting consumes fuel and flux and requires some handling labor, but the charges on these scores usually are moderate.

Screw machines produce chips in quantities so large that sometimes special conveying devices are required to handle these chips. It is not unusual for chips to equal or exceed the weight of metal in the parts produced and the total metal consumed is often double or more that required in the equivalent sintered powder part. Bars and tubes used, however, are likely to cost somewhat less per pound than the powder but the density is higher than that of the sintered compact.

Ferrous chips from the screw machine commonly have little value but there is a better market for nonferrous chips and they bring a fair price though much less per pound than for bars and tubes. The purchaser of screw machine products pays for the total stock used, of course, but the owner of the machines sometimes makes all his profit on nonferrous parts through chip sales.

Dimensional Limits

Makers of powdered metal parts often stress the fact that the parts are furnished within dimensional limits so close that little machining is needed. This is a justifiable claim but it applies with almost equal force to all competing products, except sand castings, dealt with here.

When the degree of precision is compared, however, there is likely to be some misunderstanding, partly because the matter of secondary operations has to be considered and partly because dimensions parallel to the compression axis are not so easy to control as are those at right angles thereto. Die wear affects both.

One of the largest makers of porous metal bearings gives the following tolerances:

I.D. and O.D. up to 1½ in.	+0.000	−0.001 in	Plain and flanged bronze bearings
I.D. and O.D. 1½ to 2½ in.	+0.000	−0.0015 in.	
I.D. and O.D. over 2½ in.	+0.000	−0.002 in.	

I.D. up to 1¼ in.	±0.015 in	Thrust bearings in bronze
I.D. over 1¼ in.	±0.005 in.	
O.D. up to 1½ in.	±0.005 in.	
O.D. over 1½ in.	±0.010 in.	

Length up to 1½ in.	±0.005 in.	Plain and flanged bronze thrust bearings
Length 1½ to 3 in.	±0.0075 in.	
Length over 3 in.	±0.010 in.	
Thickness	±0.0025 in.	

Concentricity (total indicator reading)

Up to 1½ in.	0.003 in.
1½ to 3 in.	0.004 in.
Over 3 in.	0.005 in.

In a few cases iron bearings are held to slightly closer limits than for bronze. It is also stated that "tolerances closer than standard are met for special requirements at added cost."

Since, when compacts are sintered they change in dimensions, it is common practice, when close dimensions are specified, to size the part by coining or by forcing it through a sizing die that compresses the part in one or both dimensions (diameter and length) and also makes it surfaces smoother without removing metal. This, of course, is a secondary operation and, as such, must be compared with possible secondary operations on competing parts. These can be performed, in most cases, in the same type of dies and with similar presses, if desired, on competing parts. The latter are more generally sized, however, by shaving dies or light cuts in other machines or, in the case of screw machine products, by an operation, such as skiving cuts or burnishing, done in the screw machine itself.

Naturally, the purchaser of powdered metal parts is not much concerned, as a rule, with the method by which a part is sized as long as the part comes within specified tolerances. But, when close sizing

requires a secondary operation, he is justified in inquiring whether, in an alternative part, the same results are not attainable (as they usually are in this case) by the same or by an equivalent operation.

Considering the sand casting, it is clear that it cannot be produced, *as cast,* within limits nearly so close as for a sintered compact. But in some cases, especially for nonferrous parts, a light cut or two will bring significant portions within required limits. This is likely to cost more, however, than on the corresponding sintered powder part.

In die casting, the usual dimensional tolerances as cast are: ±0.001 in. per in. for zinc alloys, ±0.002 in. per in. for aluminum alloys and ±0.003 in. per in. for copper alloys. This applies to dimensions controlled by solid parts of the die. If the measurement is across a parting or is controlled by parts having relative motion, somewhat wider tolerances are required. Where closer limits are needed, they sometimes can be held, as cast, but often they require a shaving, turning, reaming, broaching or similar operation. The as-cast limits are, however, nearly if not quite as close as for sintered powder parts and, when secondary operations for both are included, the differences can be made nil.

For stampings, too, (especially those needing only blanking and piercing operations, usually compared with thin parts of powdered metal) close limits are held when dies are kept sharp and close to initial size. As wear occurs, dimensions change accordingly, much as for powdered metal parts. Secondary operations, such as shaving, coining, drilling or reaming may be needed but the net result can be made about the same as for sintered powder parts and for die cast parts. Where considerable forming or drawing operations are required, the variations may be wider as springback and variations in metal hardness affect the results secured.

Commercial tolerances on decimal dimensions of screw machine products are usually from ±0.002 to ±0.005 in. on diameters and about ±0.003 in. on lengths. It is possible, however, to hold ±0.001 or even ±0.005 in. on diameters or lengths, at least in some cases, without secondary sizing, although extra cuts may be needed. Again, the limits are about the same as for the sintered powder product.

Smoothness of Surfaces

There are no qualitative data, as far as the writer is aware, on the relative smoothness of surfaces on the products here compared. It can be said, however, that the part made from sintered powder metal has an exceedingly smooth feel. This smoothness is imparted first by making the compacting dies very smooth and, second, by the "ironing" action of coining or other sizing dies.

Stampings can have equal or even superior smoothness, especially if made from cold rolled or polished sheet or if coined, but sheared surfaces, unless they are shaved or improved by some other operations, are likely to be comparatively rough.

In screw machine products smoothness (except for any surfaces left as rolled, drawn or extruded) depends upon the character of cut and the sharpness or type of tool used in cutting. High smoothness results from skiving, burnishing or reaming and from some other cuts.

Die castings take on a smoothness closely approximating that of the die surfaces. If these are polished, as they often are, as-cast finish is remarkably smooth. In the most used (zinc-base) alloys, only buffing is needed on most surfaces to make them ready for plating. At partings, grinding is often required, but this and other secondary operations yield surface of smoothness hardly surpassed by that of other products here considered. Brass die castings tend to be rougher than other types, as cast, because of heat checking and oxide deposits, but can be made as smooth as any by secondary operations.

Sand castings are not very smooth as cast but can be machined to any required smoothness. This often requires deeper cuts than are needed on other cast parts.

All types of parts here considered are subject to local roughness in the form of flash or burrs. These are removed by similar means in all cases. Tumbling is a preferred method and usually is cheapest, but many other operations such as sanding, polishing, buffing, scratch brushing and filing can be applied.

Inserts

None of the products dealt with here possess certain types of properties that can be attained through the addition of inserts but sintered powder metal products, especially bushings, often are used as inserts in all of the competing products named. In some of these, metal is cast around the insert. In other cases, inserts are applied after the major unit is formed. This latter is usually the only way of applying inserts successfully in stampings, sand castings and screw machine products.

In some instances, especially in the type of powdered metal product that has a plastic binder, inserts sometimes are placed in the die and the compact is formed around them. Subsequent sintering or baking make the insert, at least in effect, an integral element of the part thus formed. This increases the utility of the product. The same effect is secured in die casting with corresponding benefits, but does not yield satisfactory results, as a rule, in sand casting.

Conclusion

There are other headings under which it is sometimes profitable to compare parts made from sintered metal powder with competing products but the major headings are those already considered. In effect, it is necessary in arriving at logical conclusions, to follow a course of reasoning similar to that given above, if the optimum choice from among competing products and methods is to be made.

When there are "must" requirements that definitely bar out one or more of the products or methods, these can be crossed off the list. But only when those remaining are fairly evaluated is the most favorable answer certainly attained.

Characteristics of Low Alloy High Tensile Stee

by J. K. ZANETTI, *Chief Contact Metallurgist, Great Lakes Steel Corp.*

THE EXPERIENCE AND KNOW-HOW gained during the war by both designer and fabricator has certainly gone a long way in dispelling the caution and mystery surrounding the use of high tensile steels. Applications have been confined primarily to transportation equipment for weight saving and corrosion resistance; however, the experience gained in recent years by both producer and user is leading to greater diversification of application.

In general, high tensile steels can be considered to be those of low alloy content which rely on the limited use of alloying elements rather than increased carbon content for higher strengths. These steels have yield strengths of 50,000 psi. minimum, 70,000 psi. minimum tensile strength and 20% minimum elongation in 8 in. In addition, they are fine grain, often fully killed steels with good toughness and ductility at both room and subzero temperatures; some are also characterized by higher fatigue properties. Between this class and the volume tonnage of mild carbon steels lie a series of compositions of varying increased strengths over mild carbon achieved by heat treatment, cold work, or residual alloy content. Such steels certainly have their uses, but because of inferior mechanical and other properties cannot be considered to be true high tensile steels.

To the average individual the list of high tensile or proprietary steels now available to the consuming industry is confusing because of the variety of analyses. No attempt is made to give the trade name or the actual chemical analysis in the list of high tensile steels below but rather to classify them according to types.

Nickel	Chromium	Copper	Phosphorus
Nickel	Copper		
Nickel	Copper	Molybdenum	
Nickel	Copper	Phosphorus	
Nickel	Copper	Phosphorus	Molybdenum
Chromium	Silicon	Nickel	Molybdenum
*Chromium	Silicon	Zirconium	
*Chromium	Silicon	Zirconium	Phosphorus
Manganese	Copper		
Manganese	Copper	Phosphorus	

* N A X high tensile

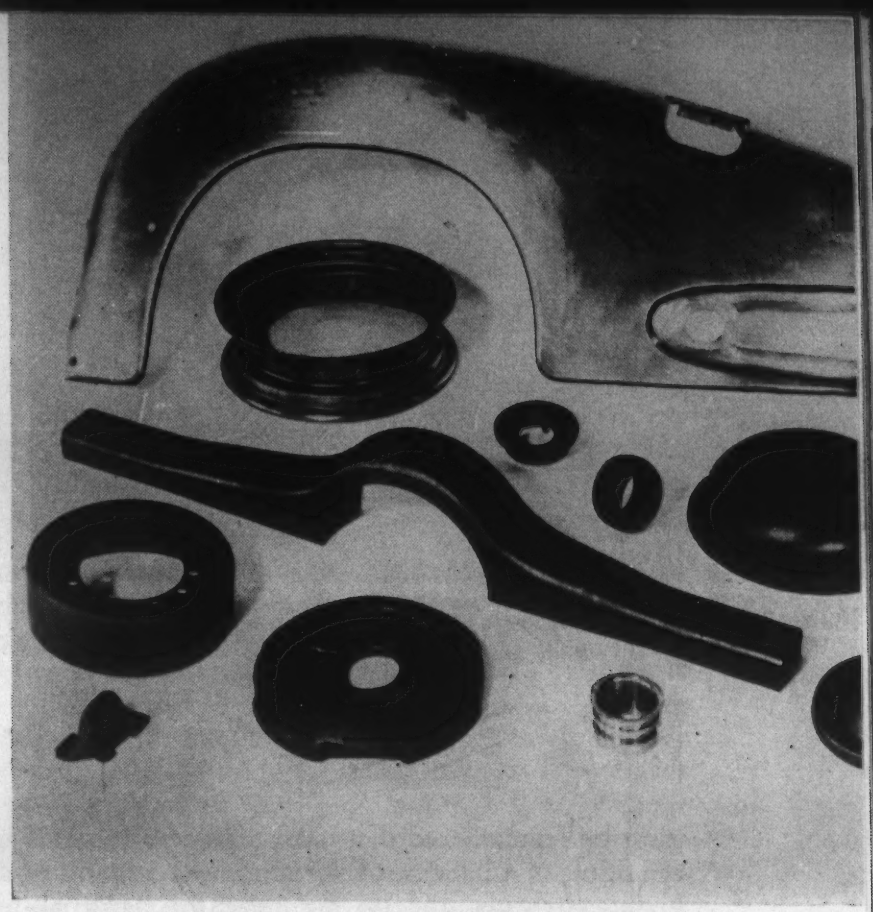
The elements present in any one of these groups are generally confined to those minima requisite to obtain desired mechanical properties associated with minimum loss of toughness when heated and quickly cooled.

Attempts have been made by both the producing and consuming industry to standardize on one or two types of high tensile steels, but because of many technical and economic reasons this was abandoned. In the first place, high tensile steels are the result of extensive research and development work and in most cases are proprietary analyses. In the second place, every steel mill has different operating conditions and the spread in the chemical limits on one particular analysis that would be necessary to permit the successful production on every mill would be far too broad to guarantee consistent and unvarying results in fabrication. In the third place, opinions vary as to what properties should predominate in a high tensile steel. Some producers believe that corrosion resistance should be emphasized and alloy their analysis to enhance this property, sacrificing to some degree formability and weldability. Others have attempted to emphasize the latter two properties while sacrificing to some degree corrosion resistance.

We have always believed that high tensile steels should contain those inherent properties which would justify its very title; namely, enhanced tensile properties plus good impact or toughness at room and subzero temperature and high fatigue strength. High tensile steels must be able to withstand stresses encountered in dynamic loading. Moreover, we believe that in order to take advantage of the above characteristics and provide for more diversified applications, high tensile steels must possess the ability to be formed and welded by ordinary commercial practices. Corrosion resistance is associated with the alloying required to secure higher strength. Extensive stationary tests have shown high tensile steels to be superior in corrosion resistance to carbon steels in number of unfavorable environments; however, until data is available on the corrosion resistance of steels under stress, we do not feel justified in emphasizing and extensive claim regarding this property. Five-year exposure tests of N-A-X high tensile to sea atmosphere show a weight loss ratio of 1 to 5 over mild carbon steel.

As can be gathered from above, the high tensile steels available to the trade today differ widely not only in chemical analyses but also in properties. The average user in selecting a high tensile steel must

Low alloy steels are readily worked and welded by equipment and methods that differ little, if at all, from those used to fabricate the carbon steels.



All of these parts were made of low alloy high tensile steel and were produced by cold forging.

therefore be guided by its versatility in fabrication and service and by its past performance record.

Require Different Handling

From the analysis and properties of high tensile steels, the average fabricator can pretty well predict that these steels will require different handling in production than the conventional carbon steels. With some knowledge and a little experience, however, fabricators have discovered that high tensile steels can be adapted to carbon steel applications in a good many jobs without any alteration of present plant facilities and practices. In most cases, the fabrication of high tensile steel does not call for any radical changes in equipment or methods. In some cases slight modifications in die or part design, or the introduction of additional steps is necessary. The adoption of good, sound metallurgical practices and modification of equipment to achieve this end has always proved to be the most economical way of production and will enable the designer to utilize the inherent properties of these steels and more than repay itself in good performance under severe operating conditions.

In general, the average fabricator is concerned with the workability and weldability of the steel that he is going to use. It would be well to consider in detail the behavior of high tensile steels as compared to carbon steels under these two types of fabrication.

Under workability we can subdivide the operations into shearing, blanking, forming and drawing. In reviewing the physical properties of the high tensile steels, it will be recalled that these steels possess a minimum yield strength of 50,000 psi. This represents an increase of from 40 to 60% in yield strength over mild carbon steels and hence there must be sufficient press capacity available to permit their successful handling. The above is not always true, as in the case of reduction in thickness permitted by the increased strength, but in general it is safe to say that in working of these steels heavier equipment is needed for the corresponding thickness of carbon steels.

These steels can be sheared or blanked without fear of troublesome edge cracking. In fact, on cutting, high tensile steels have a smoother sheared edge surface and less drag than is commonly encountered on low carbon steels. It might be well to mention here that on heavier gages, in the absence of shearing capacity, they can be flame cut without the necessity of preheating or postheating.

In forming—by which it is meant those operations involving rolling or bending—high tensile steels compare favorably with carbon steels. They can be bent or formed to almost any shape possible with carbon steels. However, greater allowances must be made for springback.

In drawing operations not all high tensile steels perform the same. We can only speak from our own experience and say that with the present die design and handling, high tensile steels cannot equal the performance of low carbon steels on all jobs, but it is surprising to a good many people, the parts that have been made.

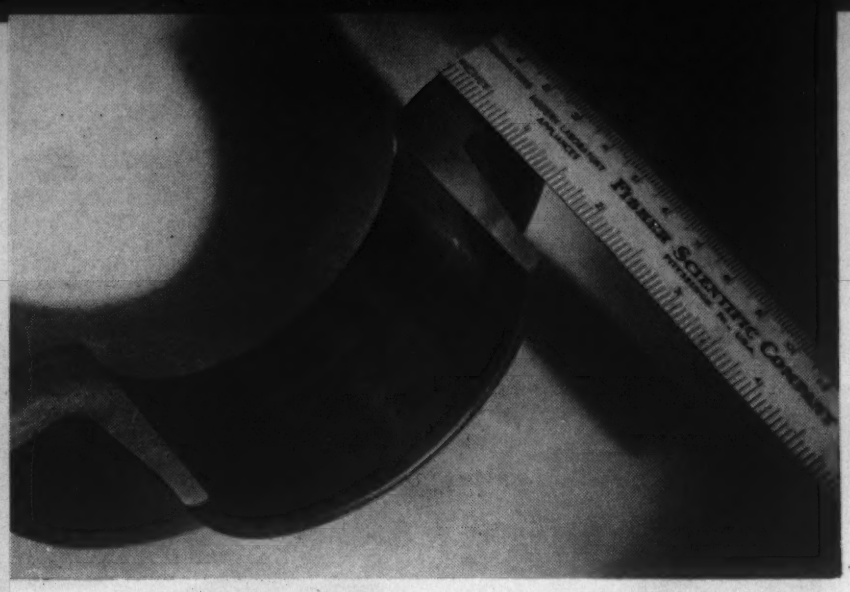
Welding High Tensile Steels

Because welding results in high localized temperatures and the resultant stresses therefrom, the trade has come to realize that not all steels behave in the same manner after having been subjected to this process. Various terms have been applied to describe a steel's reaction to this process, but the one most commonly used is weldability. As the industry has not as yet come to agreement as to the exact definition of this term, I would prefer to use that used by Dr. Wendell F. Hess in his article "Recent Progress in the Scientific Application of Welding to Steel." "Weldability is the ability of a metal to pass through a welding process without metallurgical damage." This metallurgical damage results in a loss of ductility in the heat affected zone and renders the structure more susceptible to other than uniaxial stresses. The amount of damage in the heat affected zone is dependent on the analysis of the steel and the type of welding process employed. Based on the amount of metallurgical damage done to any particular grade of steel, the widely used welding processes are listed in the order of their increasing damage:

1. Gas Welding
2. Arc Welding
3. Resistance Welding

This list is based on the cooling rates attained in the heat affected zones by the above processes.

Because high tensile steels contain alloying elements which result in certain hardening tendencies when heated, it is with concern that the fabricator views the use of these steels on parts involving welding. It



Shown here is half of a tube flange cold forged from ¾-in. low alloy high tensile steel plate

must be remembered that most high tensile steels are the result of a balance of the minimum amount of alloying elements, and do not have the hardenability that is commonly associated with alloy steels. Furthermore, through experience, the steel producer has learned to adjust his analysis to fit the various types of applications, and with the refinements in welding equipment and techniques, it has been found that high tensile steels can be welded into a satisfactory job comparable with carbon steels.

In gas welding, the rate of cooling in the heat affected zone is slow enough to make the welding of high tensile steels no problem at all.

When considering that a high percentage of high tensile steels produced are in gages under ½ in. and that a considerable amount of this is under ¼ in., it can be safely stated that high tensile steels are readily weldable by the electric arc method with the same techniques and electrodes as used on carbon steels. In the gages over ½ in. where the mass cooling effect of the steel is much greater than in the lighter gages, it is sometimes necessary to employ a method of controlled heat inputs. Developed during the war was a hydrogen-free type of electrode, which is certainly applicable to the welding of structures where heavy gage high tensile steels (over ½ in.) are used to reduce the hazard of cracking in the weldment or underbead with its eventual propagation into the heat affected zone.

Because of the tremendous cooling rates associated with electrical resistance welding, the problem of obtaining optimum welds in high tensile steels comparable with optimum welds in carbon steels in heavier gages requires deviation from normal resistance welding equipment and technique. It might be well to point out here that in most resistance welding applications of carbon steels it is not necessary to obtain the optimum weld, whereas with high tensile steels because of the increased yield strengths and more severe operating conditions to which the weld will be subjected, it is much more important that the optimum weld be obtained.

Better Resistance Welding Developed

The vastly increased use of high tensile steels during the past five years has initiated a parallel interest in the development of new and better techniques for resistance welding of these steels. Such developments have been the objective of well organized academic research programs carried out in properly equipped laboratories, and also have received the sincere interest of large manufacturing and fabricating industries where practical industrial researches and applications have been studied. As in all new investigations of this type, certain difficulties have been encountered, but have also been surmounted, and it can truly be said that the work along these lines has yielded a very sound and more thorough understanding of the metallurgical, mechanical, and electrical factors which govern the consistent production of good resistance welds. It is also true that these studies have shown that in many cases there has been, and still is, very much to be desired from a standpoint of quality in the resistance welding of plain carbon steels.

In the term electrical resistance welding, we generally include the following types of welding:

1. Spot welding—of which projection welding is a special type
2. Butt welding
3. Flash welding
4. Seam welding

Of these four types of resistance welding, by far the greatest amount of work has been done in the spot welding field. This is probably so because in the first place the volume of fabrication by spot welding methods is far in excess of the others, and secondly the spot welding process and the equipment used can be more easily adapted to make use of certain basic metallurgical knowledge concerning heat treating and annealing cycles which greatly improve the weld quality.

Probably one of the first organized research programs, having for its objective the development and improvement of methods of spot welding low alloy high tensile steel, was carried out under the auspices of the Great Lakes Steel Corp., by C. R. Schroder who is now at the welding laboratories of the Rensselaer Polytechnic Institute. The program was successful and launched a definite interest in this field, together with a series of successive research programs at the above mentioned laboratory and at other laboratories and industrial plants. The results of these researches have established greatly improved procedures for quality spot welding of not only low alloy high tensile steels, but also for higher alloy and higher carbon SAE and NE-8600 and 8700 grades.

In the original work at Rensselaer, titled "The Spot Welding of N-A-X High Tensile Steel," certain basic and general principles were established and have since been reconfirmed by further academic work and by numerous industrial field applications. These general principles may be listed as follows:

1. Low alloy high tensile steel can be very successfully spot welded from a quality standpoint.
2. In single pulse welding of the lighter gage thickness (0.100-in. and under) the weld metal cooling rates are of such magnitude (5,000 to 10,000 F per sec.) as to make carbon, and not contained alloy, the principal metallurgical factor for consideration, and consequently all spot welds in these lighter gages, whether the steel be plain low carbon, low alloy high tensile, high carbon or high alloy, can be greatly im-

proved from a standpoint of strength and toughness by the use of annealing or heat treating pulses in the welding machine. This, of course, will increase fabrication time, but the viewpoint is quickly gaining prominence that the vastly improved quality of the weld, coupled with the inherent property advantages of a high tensile steel, will more than offset the time element. Such a viewpoint has been openly expressed by an authority who is employed in a responsible capacity by a large automotive fabrication plant, and who has directed considerable practical research for that concern in their own plant. It is an encouraging thought that fabricators are gradually leaning toward this viewpoint, and stressing the quality aspects.

3. In spot welding heavier gages, the contained alloy and hardenability become more important as determining factors, and in such cases very successful cycles have been worked out in the pulsation welding, as well as the heat treating or annealing and austempering field.

4. The improvement obtained by heat treating or annealing welds in low alloy high tensile steels is marked when present-day quality testing methods are used, and is far more marked than is the case with the plain carbon steel. However, it should be emphasized that in many cases the mechanical aspects of the testing methods are actually more important than the metallurgical aspects. In tests, where the weld is stressed normal to the welding surface, the considerably lower yield strength of the plain carbon steels will allow for quicker distortion of the base metal which will immediately relieve certain stress concentrations on the weld metal to heat zone fusion line, and will consequently make for the appearance of a more ductile weld metal, whereas the actual metallurgical toughness of a properly welded high tensile steel spot weld may even be better. It must be remembered that no proper spot welding design will allow for stresses which will produce plastic distortion of the base metal surrounding any one spot, and therefore it is evident that properly made spot welds in high tensile steels will certainly stand higher service stresses than is the case with plain carbon steels.

5. Along with developments which have been accomplished in the field of spot welding, it is important to note that the resistance welding machine manufacturers have made great strides in developing new equipment which is of great advantage in welding high tensile steels. Such equipment includes new and more elaborate electronic control and timing devices which allow for automatic control of welding pulses, welding amperage, and time of hold between pulses, and also more accurate devices have been developed for better control and measurement of pressure, together with provision for higher working pressures which are a distinct advantage when welding the high tensile steels.

The above considerations pertain to optimum quality in spot welding high tensile steel. However, it is possible to obtain satisfactory welds with sound present day welding practice. To obtain the best results is may be mentioned that the following general principles should be considered when resistance welding these steels:

1. Increased pressures, especially when fit-up is poor.
2. Slightly decreased amperage combined with a slightly increased time in cycles.
3. Closer attention to proper electrode dressing and preparation.

Observance of the above will pay dividends, not only in spot welding high tensile steels, but also in other resistance welding applications such as seam, butt, and flash welding.

In the fields of seam and butt resistance welding, it is a distinct advantage to adjust the cycles using higher pressures and longer time-on periods with shorter time-off periods, with increased current frequencies wherever possible, and a corresponding adjustment of amperage. No two automatic machines are alike in their operation, and the best results can only be obtained through a little study and proper adjustment in the individual plant or setup.

Conclusion

In the past, the prime thought behind the use of high tensile steels has been the weight saving that can be effected by the higher tensile properties. This has been done in the transportation field and has resulted in greater pay loads. However, the materials engineer must always remember that not in all cases can the proportionate increase in tensile properties result in the same proportionate decrease in weight. For the same design in a carbon steel, attention must always be given to the fact that the thickness of the material must not be lightened to the detriment of rigidity. Frequently by the use of corrugations, embosses, or the new Rigidtex process, the sectional modulus can be increased to effect the maximum allowable weight saving.

We believe that, disregarding the weight-saving feature of high tensile steels, they can more than pay for their added cost by decrease in maintenance expense and longer service life because of higher impact, fatigue, abrasion, and corrosion properties. These are intangibles as far as present day cost estimates on new designs are concerned, but when put into service over a period of years will undoubtedly reflect in a reduction in overall cost of operation.

Frequently the properties of high tensile steels can actually effect lower manufacturing cost due to decreased working or handling cost. It has been found on some applications that cold drawn high tensile parts, incorporating design changes compared very favorably in strength with heat treated parts of higher carbon material. The higher carbon material, in addition to having to be hot worked and heat treated, had much higher grinding and buffing cost in preparation for plating because of the heating operation. It has been found that some high tensile steels, because of their strength and cold forming properties, lend themselves economically to applications where increased styling with maintenance of strength is desired.

At times there are applications where weight saving is unimportant structurally, but its use results in less handling cost, particularly where hand labor is used, and also less freight cost.

Much of the value of carbide tooling is lost due to the fact that older machine tools were not designed for its use; some new machine tools are.

Selecting a Machine Tool for Carbide Tooling

by T. C. Du MOND, *Managing Editor,* MATERIALS & METHODS

A GREAT FACTOR IN OBTAINING the excellent results being experienced with carbide cutting tools in industry today has been the fact that many machine tool builders anticipated the widespread use of carbide tools, with their accompanying demands for higher cutting speeds and greater power inputs in the carbide-tooled machines. Thus it was that machine tool manufacturers some years ago began to design machines which were planned for the use of carbides. Many such machines are already in use; others are being currently announced; while additional numbers are to be introduced in the near future.

It should be understood, of course, that the use of carbides is not limited to the newer machines. Experience has demonstrated that excellent results can be obtained on the older types of machine tools with carbides provided that certain considerations are kept in mind. These include: the tightening of spindle bearings and all slide gibs; seeing that the machines are free from excessive vibrations under actual operating conditions—in other words, making such corrections as are necessary to put the machine in first class condition. All of these adjustments are within the scope of a good maintenance man.

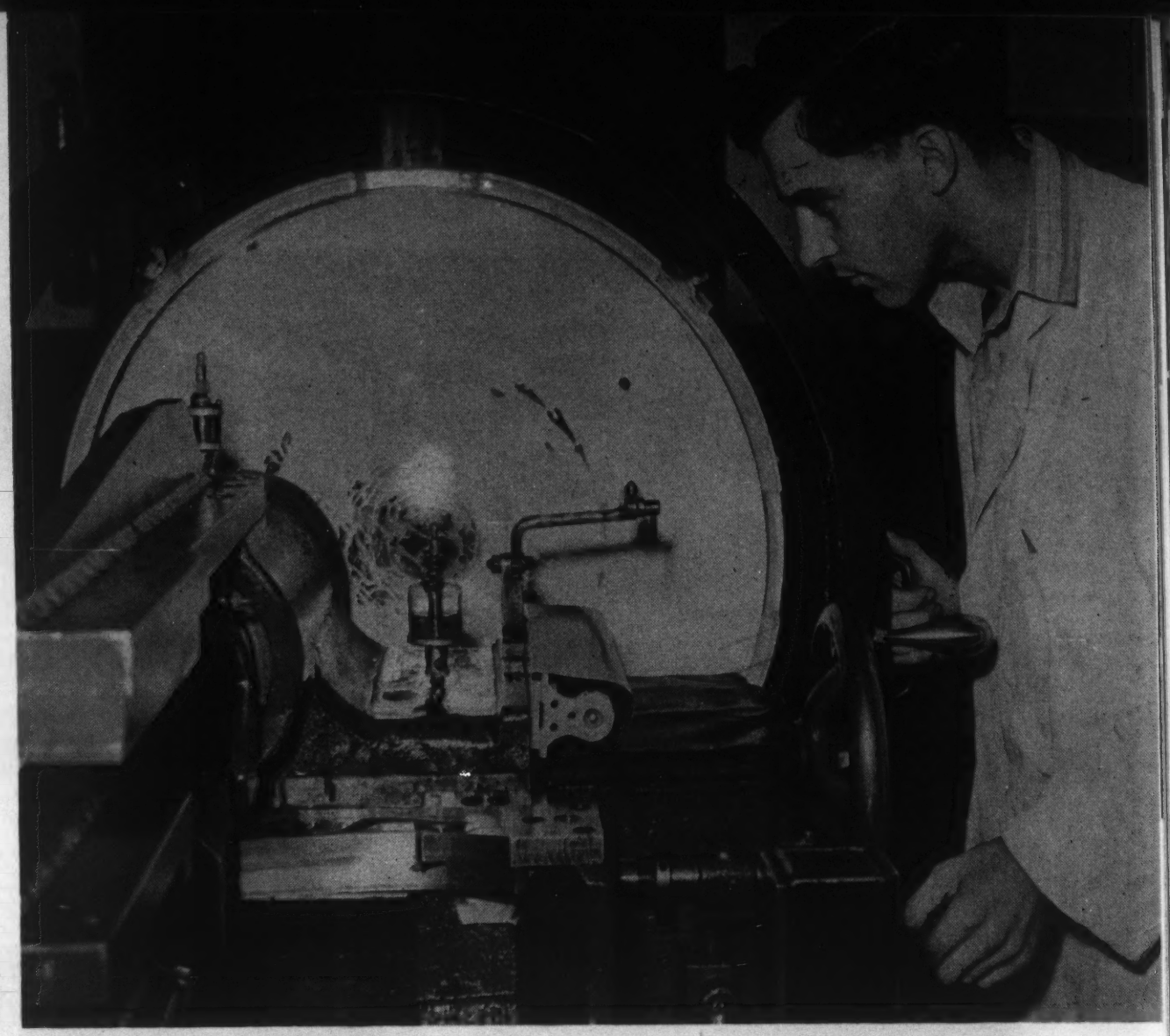
Advantages of Carbide Tooling

It is true, however, that *maximum* benefits from carbides are obtained from machine tools designed with carbide tools in mind. Quite naturally, many older machines were designed for the use of other types of cutting tools. This was reflected in operating speeds and power inputs substantially lower than desirable for best results from carbide tooling.

When carbide tools first began to become a major factor some years ago, it became obvious that for best results machine tools would have to be planned *around the tool.* In other words—it became necessary to determine *what kind of machine was needed for the tool* rather than first designing the machine and then figuring out what kind of tools to use on it. Many machine tool producers adopted this new approach and are continuing this practice to keep machines in line with progress in carbides.

In designing machines for use with carbide tools, one of the most important points to consider is that cutting speeds must be considerably higher than for high speed steel tools in order to obtain the maximum advantage from the carbides. This is particularly true in steel cutting where too slow a speed may cause a "built-up edge" on the carbide tools, resulting in rapid dulling of the tool. It also holds true for machining the "light" metals where high speeds are desired so that the heat is taken away in the chips, thereby holding the temperature rise in the work piece to a minimum.

It also has to be borne in mind that carbides possess the ability to effectively machine metals that are too hard or too tough to be cut with other existing types of tools; that they can remove more cubic inches of metal per minute—if sufficient horsepower is provided—than any other kind of cutting tools; that they are capable of holding closer tolerances over longer periods of time; operate at higher cutting speeds; that they give longer service between grinds; and that they produce a better finish on the work piece, thereby frequently eliminating subsequent machining or grinding operations. All of these advantages depend for their fullest exploitation on the manner in which the machine "uses" the carbide tool.



Carboloy carbide tools are used to machine this formed piece. A guide serves to provide a parabolic contour. (Courtesy: Chrysler Corp.)

On the other hand, carbide tools also have certain characteristics which must be taken into consideration. For instance, carbides permit somewhat less latitude in setting the tool than do other cutting tool materials, inasmuch as carbide cutting is generally done "on center" of the work piece or very close to it. Relief angles on carbide tips should be held close to recommended practice, less latitude being available than on steel tools. For maximum tool life, the nose radius should be kept as small as possible on steel cutting. Ultra-fine feeds should be avoided in order to lengthen tool life, since such fine feeds tend to wear the tool more rapidly. High frequency vibrations—set up in the work or in the machines—have a tendency to cause the cutting edge of the carbide tool to dull prematurely through minute chipping. However, it might be mentioned that—contrary to casual opinion—"brittleness" is not a practical handicap of the carbides. The ability of carbide tools to resist impact—such as those encountered on interrupted cuts or in the machining of eccentric forgings and castings—amply demonstrates the toughness of these tools.

General Machine Considerations

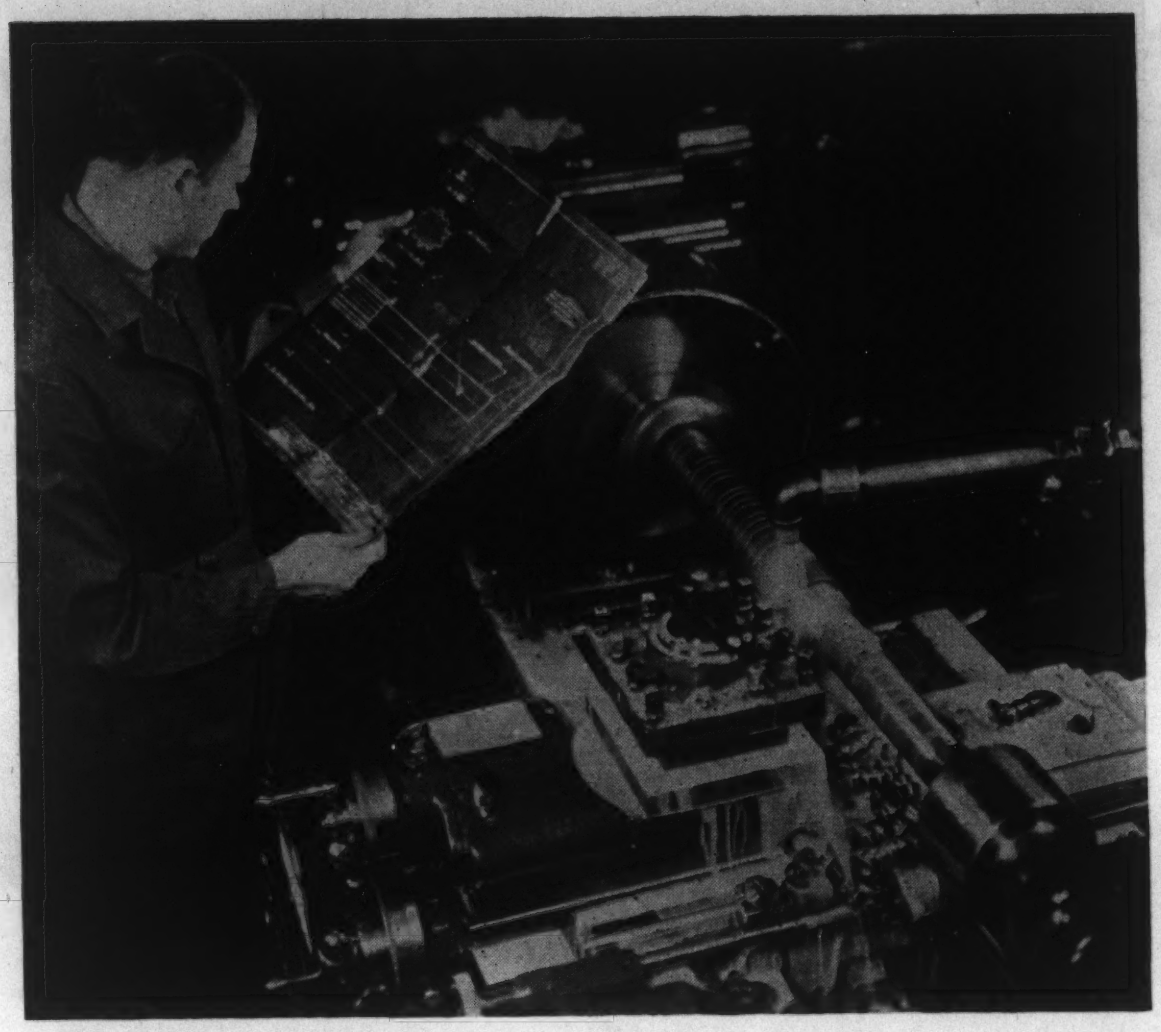
With these tool considerations in mind, it is entirely feasible to arrive at a list of qualifications, the possession of which makes a given machine tool well suited for carbides. The major characteristics of such machines are as follows:

Horsepower—To take full advantage of the increased cutting speeds made possible with carbides, higher horsepower is required. This is due to two factors. In the first place, horsepower required *at the spindle nose* is roughly proportional to the amount of metal removed per minute. Metal removal per minute is higher—because of increased cutting speed—with carbide tools than it is with steel tools. In addition to this, carbide tooled machines being almost invariably operated at higher speeds than those equipped with steel tools, means that a higher friction loss in the drive to the feed mechanism and spindle nose is reflected in additional horsepower requirements.

As an example of this, take an imaginary job of machining a steel part using a ⅛-in. depth of cut. This cut may be taken at 80 sfpm. and a 1/16-in. feed, with high speed steel tools. With carbide tools, the speed would be around 300 sfpm. (a conservative figure) with about a 1/32-in. feed. Under these conditions, the rate of metal removal with the carbide tool is approximately twice that of the steel tool. Thus, double the chuck horsepower will be required, plus an additional amount to overcome increased friction losses at the higher operating speeds. Actually in this case the ratio would be roughly 9 horsepower for the carbide tooled machine as against 5 horsepower for the high speed steel tooled machine.

Increasing the horsepower of a machine tool involves other considerations. For example—if the motor is mounted inside the machine, greater motor cooling facilities may be required. Clutches should also be of sufficient capacity to take care of the higher horsepower transmitted.

Another important point is that most carbide machine operations will be performed in the higher speed ranges of the equipment. When machines have not been specifically designed for *continuous* operation at their maximum speeds, it is quite possible



Lathes, milling machines and many other classes of machine tools will have to be designed to fit the needs imposed by carbide tools. (Courtesy: Carboloy Co.)

that many jobs may have to run at lower speeds than is desirable. Obviously if the job requires continuous machine operation over extended periods of time, machine life must be considered. This may mean that the job will have to be run at speeds below the machine's maximum. In machine tools designed specifically for carbide operation, this factor is usually—although not always—taken into consideration by the machine tool producer.

The higher speeds also involve other considerations. For instance, vibration should be eliminated as much as possible, particularly at the high machine speeds. Such vibrations tend to cause carbide tools to dull prematurely. This means that the construction of the machine tool should be more rigid, and that gears, spindles, and bearings must be designed for high speed operation without torsional or other vibration. In addition, lubrication systems must also be designed in line with the higher rotating speeds of the spindle drive mechanism.

In view of the fact that the machines operate at higher speeds, the question of "machine friction" becomes of greater importance. The horsepower required to run some machines idle at carbide cutting speeds is a higher percentage of the total required. This means that in the transition from the use of conventional tools to carbide tools, special attention has to be given to reducing high speed machine friction by the machine designer.

Chip Disposal and Control—Adequate chip disposal and control requires more consideration with carbides than with other tools because the chips are produced at a higher rate of speed. The faster flow of the chips should be controlled of course so as not to endanger the operator or damage work piece or tools. Restriction of the free flow of chips from the cut may materially reduce the machine output.

For the two general types of materials—the long-chip metals such as steel, aluminum, etc., and short chip materials such as cast iron and the asbestos compounds — slightly different considerations are generally required. In either case, of course, the machine should be so designed that chips will not be trapped where they cannot be readily removed while the machine is in operation. On some machines where the production of chips is exceptionally high, mechanical means of chip removal, such as conveyors, may be employed.

When cutting the long chip metals, a good way to prevent the chips from piling up is to locate the work piece, the tools, and holders in such a manner that the chips will "flow" away from the job by gravity.

To obtain adequate chip control with the long chip metals, the chip also must be continuously broken. This may be done either with chip breakers or curlers in the tool itself, or by directing the chip against the work piece *ahead of the cut* or—if no other method is available—against the tool holder or fixtures.

When cutting short-chip or "powdery" materials such as cast iron, asbestos compounds, silicon iron

This is a view of the carbide grinding department of the Baker-Perkins plant, where specially designed grinders are used. (Courtesy: Carboloy Co.)

and graphite without a coolant, the major chip problem is one of adequate disposal. Suction systems are sometimes used to remove the short chips and dust as rapidly as they are formed. This also has the advantage, with powdery materials, that the dust has no chance to contaminate the atmosphere.

Coolant Systems—Numerous carbide jobs are run successfully without a coolant. On certain operations, however, it is necessary to use a coolant to keep the work piece from distorting and to cool the tool and chips when machining long-chip materials.

In such cases, special attention should be given to the coolant system. It should be so designed that the coolant is directed at each cutting edge with sufficient velocity to carry the liquid into the tool point and in sufficient volume to carry away the heat generated at a rate which will keep the temperature of the tool from becoming excessive. With carbides, the conventional procedure of flooding the work with coolant is inefficient and sometimes harmful, due to the fact that the fast flowing chip forms an umbrella which keeps the coolant away from the cutting edge.

Good ways of getting the coolant where it is needed are (1) to pipe the coolant from beneath the tool; (2) to pipe the coolant from each side of the tool; or (3) to drill the tool block to form a passage for the coolant through the block. The fluid system permits an unobstructed flow of the liquid coolant under the chip to the nose of the tool.

On carbide-tooled machines, coolant reservoirs and pumps should have ample capacity. It is particularly important that the reservoirs be large enough so as to eliminate the possibility of the coolant becoming too hot during a long run.

Work Chucking—Due to the tremendous reduction in the cutting time made possible when machines are tooled with carbides, greater emphasis is automatically placed on the necessity to reduce the time required to load and unload the work piece as this time cycle becomes a considerably greater proportion of the floor-to-floor time per piece machined. As a result, considerable attention has to be given to the possibilities of expediting the loading and unloading of parts. This, of course, involves basic machine design as well as such accessories as may be provided to reduce the loading time.

Chucks should operate easily and rapidly. Such devices as retracting tail stocks and automatic chucking mechanisms—operated by electricity, compressed air, hydraulically, or by cams—offer greater proportionate advantages when carbide tools are used.

An important point to remember in this connection, however, is that the higher cutting speeds with carbides do not in themselves impose greater loads on the work, on the work holder, or on the tool. More often than not, the opposite is true and the increased speed is actually accompanied by a *decrease* in tool loads and torque.

Work Handling Devices—Quite naturally, reduced floor to floor time decreases the intervals between unloading and loading the machine. Where the work pieces are large, this may make it desirable to con-

sider the possibility of using devices to reduce the amount of manual handling necessary. Thus, machine tools should be designed so as to facilitate the employment of work handling devices.

For example, suppose that the rough work piece weighs 18 lb. and that at the end of the operation its weight may have been reduced to, say, 13 lb. Further assume that, with high speed steel tools, 45 pieces were produced per hr. Now if this same machine is tooled up with carbide tools, it may produce something like 96 pieces per hr. As a result, the total weight to be handled may be something like 2976 lb. per hr.

Devices which assume the major portion of the burden of work handling and which also actually shorten the unloading and loading periods are a help in such cases. Such devices may be found not only to increase production but also to reduce worker fatigue.

Tool Holders—Where possible, tool holders should be designed to take "standard" shapes and sizes of carbide tools. Non-rocking type holders have been found to give the best results with carbides since rocking type holders permit errors in setting and either increase or decrease clearance and it is important that carbide tools be located accurately in relation to the work. Such tools should also be supported as close to the work as possible. Tool holders should be designed to facilitate and insure correct setting and alignment of the tools after each re-grind without the operator having to determine the correctness of the setting. In addition to safeguarding the tool and insuring better work, such holders also reduce downtime required for making tool changes.

Tool Changing—When purchasing a machine tool on which carbide tools are to be used, it will be well to check the arrangements provided for rapidly changing the cutting tool.

Under ordinary conditions, only the time element is involved in rapid tool changing. However, in some of the more recent "carbide milling" machines, the combined weights of the carbide cutter and the flywheel may be 275 lb. or more. In such cases, it will be found worthwhile to provide a fixture of some sort for tool changing. One suggestion is the use of a frame, or jack, which not only supports the cutter assembly but also helps to lift it into the correct position.

Specific Requirements

LATHES—An important consideration in lathes intended for use with carbides is that carriage and compound should be exceptionally rigid. It is also well to make sure that the carriage design is such that cutting loads are absorbed as nearly as possible in a direct line through the carriage supports.

Ways should be so designed that they will wear evenly. Wide ways also add to the rigidity of the entire setup, in addition to distributing the load and reducing the wear. The possibility of using ways made of cemented carbide might well be kept in mind for the future. Experience with lathe ways made from this hardest of all powder metal products indicates that such ways not only outlast comparable steel ways but that they also wear more evenly over their entire surface.

Heavy, rugged tailstocks are particularly desirable for carbide work, especially when heavy cuts are to be taken at the tail stock end of the work piece. A machine designed with considerable rigidity throughout can easily lose much of its quality for carbide cutting if the tailstock is so light that it deflects under high load.

Revolving centers have been found to be advantageous since "rubbing speeds" in carbide cutting operations are usually high enough to be an important cause of wear and burning. Live centers, of course, eliminate this. In this connection, too, it might be well to note that carbide centers wear less than steel ones.

Provision of a vertical adjustment for tool holders in carbide tooled lathes makes possible the quick and accurate adjustment of the tools after each tool re-grind. These make possible the resetting of tools to the correct cutting position which, as mentioned, is somewhat more critical with carbides than it is with high speed steel tools.

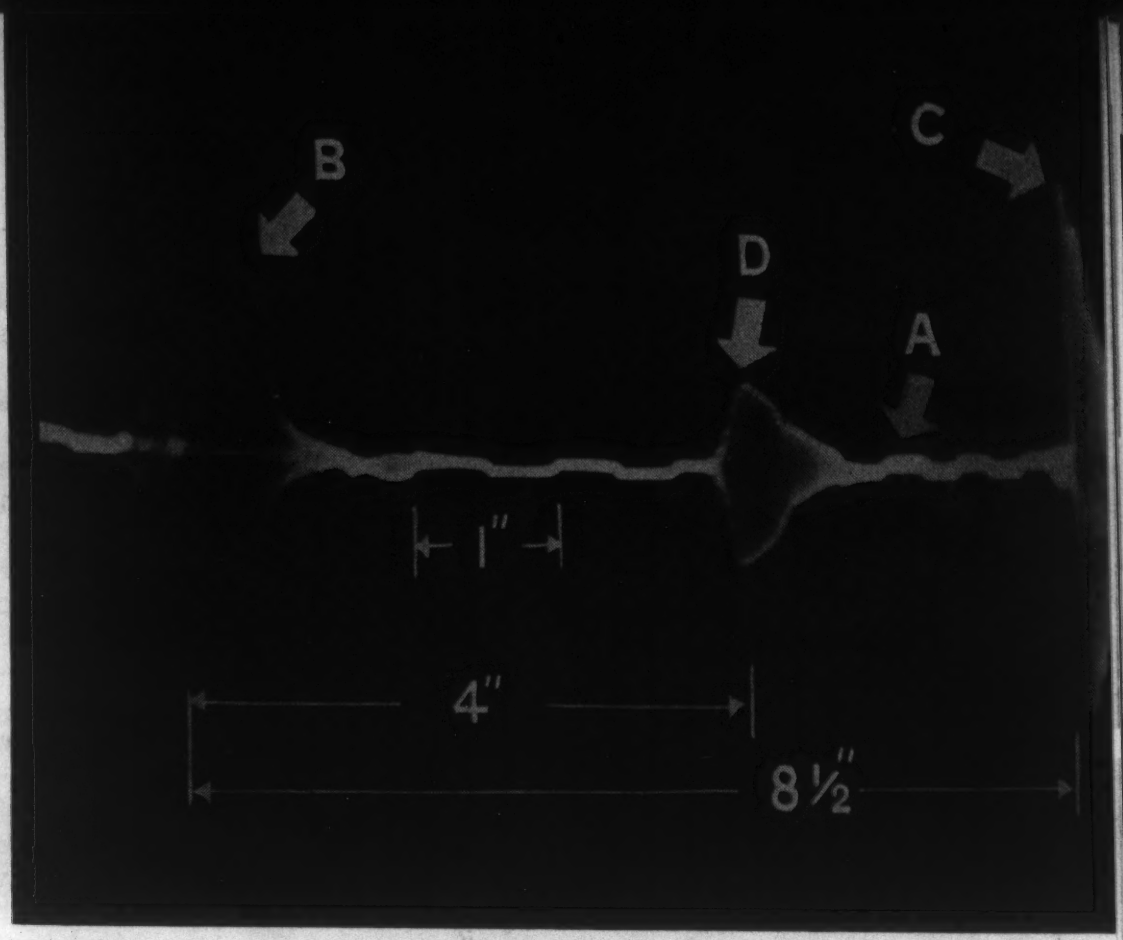
MILLING MACHINES—Carbide cutters can be used on practically any type of milling machine. However, bed type milling machines seem to offer certain advantages over other types for carbide milling because of their greater rigidity. It is also desirable to select a milling machine which can be used for climb milling when desired.

One of the most important items to bear in mind when using a milling machine tooled up with carbide cutters is to make certain that there is enough mass in the cutter drive to smooth out the cutter operation. On most machines, this necessary inertia can be obtained by using a flywheel. The size and weight of the flywheel is determined by the particular machine and the operating conditions. It is usually mounted on the spindle. However, it should be pointed out that there are carbide milling machines on the market today which do not require separate flywheels since they have the needed "flywheel characteristics" built into the drive.

The chief reason why flywheels are desirable with carbides is that the impact per tooth is considerably higher than it is with high speed steel tools due to the higher cutting speeds. The correct design of flywheel to use on the various types and sizes of milling machines can best be determined by trial and error, or by consulting your machine or carbide tool supplier. The diameter of the flywheel should usually be larger than the diameter of the largest gear in the drive.

A progressive gear shift seems to be preferable to the step-up step-down type of shift since it insures that all internal rotating parts will be operating at the lowest possible speeds.

V-belts and worm drives have the advantages of smoothness or drive; and a minimum of vibration. Worm drives, where they eliminate several gears—and particularly when located close to the spindle nose—also have the advantage of reducing total backlash.



A typical reflection pattern on the Reflectoscope oscilloscope. A—base line graduated in inches of thickness; B—indication of the initial sound pulse; C—reflection of sound wave from opposite side; D—reflection of sound wave caused by a defect.

Supersonic Inspection of Materials

by H. R. CLAUSER, *Associate Editor,* MATERIALS & METHODS

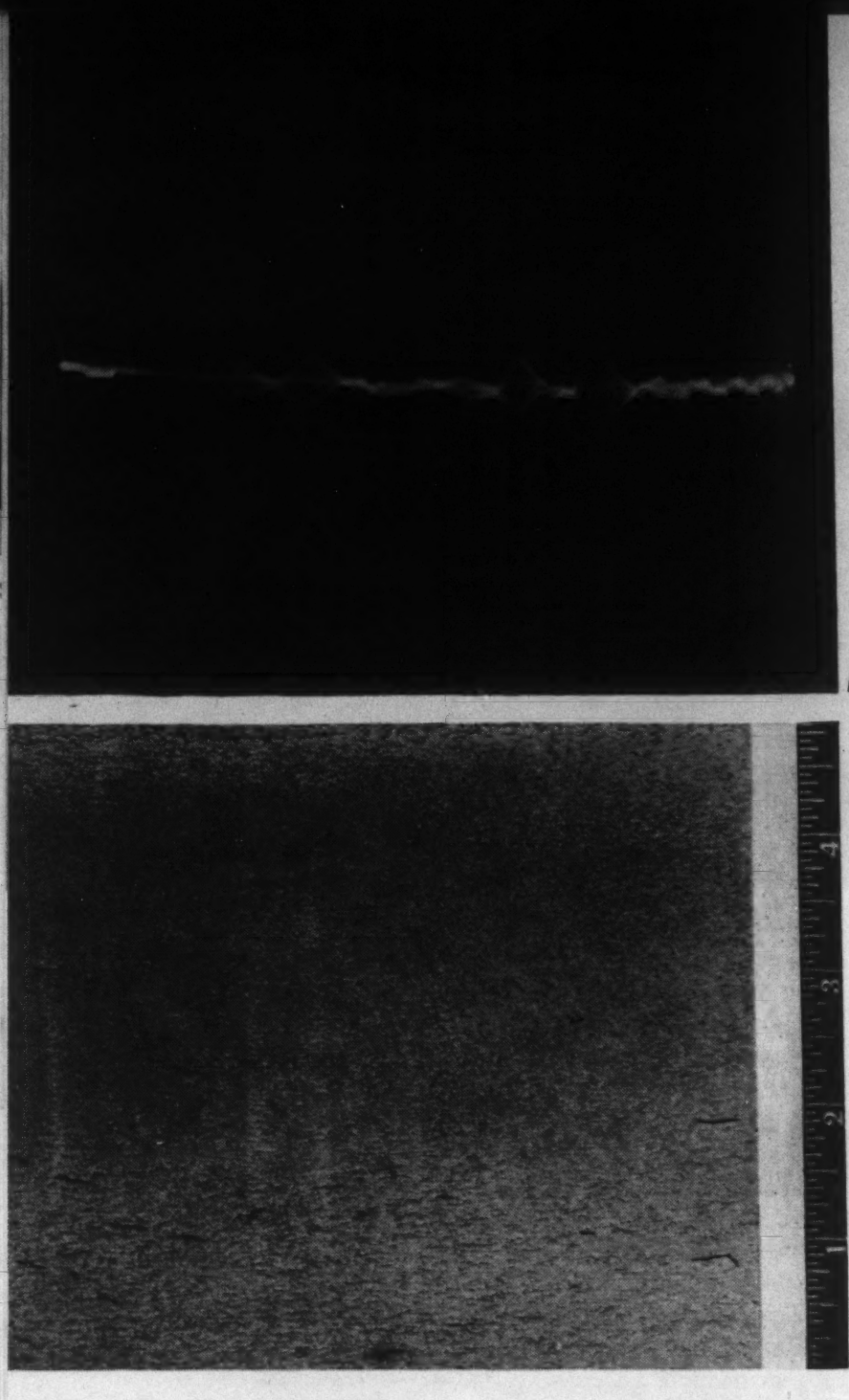
SUPERSONIC INSPECTION METHODS have been developed within the last few years to the point where they now rank with other non-destructive testing tools, such as radiography, as a means of detecting flaws in materials. In order properly to evaluate the place of supersonics in the field of flaw detection two principal supersonic methods must be considered—the reflection method and the through-transmission method.

The use of sound to inspect materials is not new. Several sonic methods have long been in use. In one of these methods the article to be tested is vibrated so as to emit a sound and the tone is checked against that of a standard specimen to detect presence of flaws. In another method, the duration of the sound given off when the specimen is struck is measured and compared with a standard. Methods such as these are only qualitative and are not too precise. They can only tell whether a piece is good or bad and can indicate nothing about location or size of flaws. Because of these limitations, they do not have wide application.

Inaudible sound waves are used in two ways to perform non-destructive inspection of materials to determine and locate voids and other type flaws.

Also, sonic methods of inspection until recently were limited to the use of audible sound waves, whereas supersonic sound waves (sound waves with frequencies above the audible range, i.e. 20,000 cycles per sec.) have characteristics which make them much more useful for materials inspection. Supersonic waves are of short lengths which are reflected from small flaws, while audible sound with long wave lengths flow around and past flaws without appreciable reflection. Another useful property of high frequency, short wave length sound is its ability to travel in a straight line with a search-light effect instead of scattering and bending around corners as does audible sound. Further, supersonic waves are able to penetrate thicker sections of materials such as steel and aluminum. Because of these properties, it is possible with supersonics to examine the interior of thick materials and accurately to locate any discontinuities present.

The basic methods of utilizing supersonics for the inspection of material have been developed. In one



The supersonic reflection method is useful in detecting flaking in steel. (A) Shows a typical reflection pattern indicating the presence of flaking; (B) shows the cross-section of a 5-in. piece of forged steel with a number of flakes of the type revealed by supersonics.

of these, the reflection method, supersonic waves are passed through the material and the waves reflected from the opposite side or from flaws are observed. In the other, the through-transmission method, the change in energy level of the sound beam when it passes through the material is noted.

The Reflection Method

It is well known that matter such as metals, plastics and liquids transmit sound much better than air. When supersonic waves are transmitted through a piece of material and hit air, the waves are practically stopped and reflected back towards the point from which they were sent. Also, if a discontinuity exists in the material, it will reflect the portion of the beam hitting it.

This reflection or echo principle is utilized by Sperry Products, Inc., in their Supersonic Reflectoscope. Sound waves are sent into the part and measurement is taken of the length of time it required for these vibrations to penetrate the material, reflect from the opposite side or from an internal flaw, and return to the sending point, is measured.

The essential parts of the Reflectoscope are:

(1) A generator which creates the supersonic waves by applying an oscillatory voltage to a quartz crystal;

(2) The quartz crystal which radiates the sound waves into the material and also receives the back reflections;

(3) An electronic amplifier which amplifies the reflected sound waves; and,

(4) A cathode-ray oscilloscope which measures the round-trip time of the waves. It can be calibrated for each type of material to indicate visually the thickness of the material and the location of the flaws.

To operate the Reflectoscope, the quartz crystal is placed on a flat, relatively smooth surface of the material being tested, after this surface has been covered with a light film of oil or glycerine to improve the sound transmission from the crystal to the material. The oscilloscope pattern is then observed as the crystal is moved over the material. If the piece has no flaws the two peaks which show on the calibrated oscilloscope indicate the two edges of the piece. If discontinuities are present they will be indicated by additional peaks showing between the "edge" peaks.

The equipment employs supersonic waves with frequencies in the 500 to 12,000 kilocycle band. The nature of the material, the kind of flaws being investigated, and the size of the test specimen, usually determine the frequency as well as the size of the crystal used. The size of the crystals vary from ½- to 2-in. square. The crystal sends out the waves in pulses of a few microseconds duration at a rate of 60 times per sec. Between these transmitting periods the crystal picks up the reflections, generates a small voltage which is amplified and shown on the oscilloscope.

The Reflectoscope is compact and portable; it is mounted on wheels so that it can be moved about readily. Where desirable, arrangements can be made to obtain a permanent record of the results by mounting a camera over the oscilloscope.

Applications of the Reflection Method

Most metals and plastic materials can be inspected by the reflection method. The depth of penetration which can be achieved in a given material depends chiefly on the size of the grain structure and the forming method used in fabrication. Coarse grained materials like copper and lead are more difficult to penetrate than are substances like aluminum and steel. Forged and wrought products are easier to get through than cast parts. Listed below are the maximum thicknesses of various materials penetrated in tests conducted with Sperry's Reflectoscope.

Aluminum	28 ft.
Steel	28 ft.
Magnesium	30 ft.
Brass	2 ft.
Copper	6 in.
Bakelite	3 in.
Glass	2 ft.

It should be noted that the above figures are only approximate since the depth of penetration of two pieces of a particular material may not be exactly the same. They are not necessarily the final limit nor do they indicate that penetrations of that order can always be achieved. The reflection method is generally not good for thicknesses below ½ in. This is due to the fact that the transmitted pulse covers approximately the first ½ in. or so on the oscilloscope and therefore it hides any flaw indications which might be present in that area.

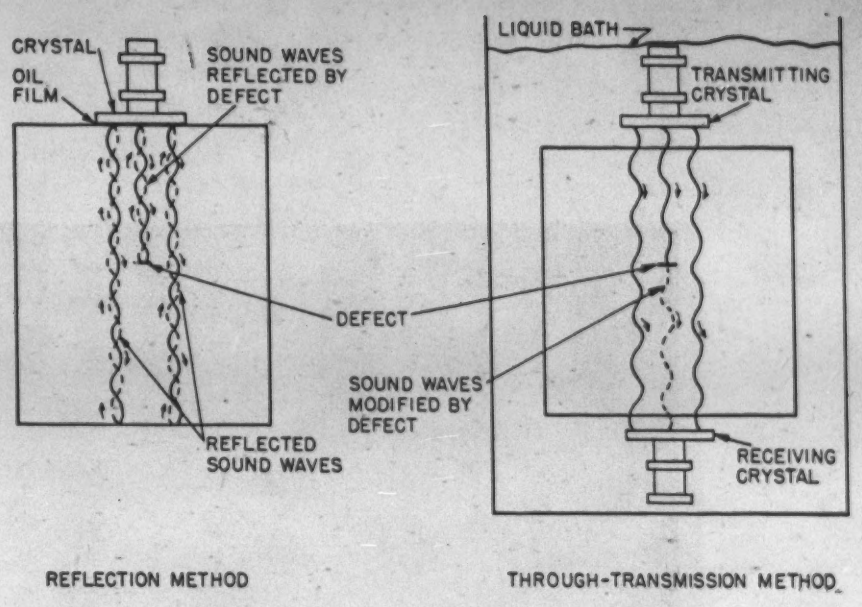
The shape or form of the material to be inspected must be such as to provide an intimate contact between the crystal and the surface. The area of contact must be at least as large as the searching crystal for best results (½ to 2 in.). Parts with flat surfaces are of course the most convenient to inspect; however, it is possible to inspect curved sections, but the searching crystal must conform to the shape of the surface. Thin walled and irregular shaped pieces, such as many die castings, cannot be inspected. The backwall (the wall which reflects the sound beam) must be approximately parallel to the surface on which the searching crystal is placed. Although it is sometimes desirable to inspect a part from several sides for complete diagnosis, only one side of the test sample need be accessible.

As previously mentioned, it is necessary to have intimate contact between the crystal and the surface of the material being inspected. Poor contact results in distortion of the initial pulse, unsatisfactory transmission and reflection of the sound beam. To achieve this good contact, the surface must have a smoothness equivalent to the G-E roughness standard of f 5 or f 6. A smooth surface of this type can be obtained with a surface grinder.

The reflection method of supersonic inspection will locate internal defects which present a reflecting surface to the sound beam as it passes through the material. The minimum size defect which can be detected is one having a projected lateral area equal to 0.1% of the distance from the searching crystal to the defect. For example, at a distance of 10 ft. from the crystal it is possible to locate an ⅛-in. defect; at 6 in., the smallest detectable defect would be 0.006-in.

The distance of the flaw from the surface on which the crystal is placed can be determined accurately within ⅛ in. By moving the crystal around on the surface at the point where a flaw is detected, the extent of the flaw can be outlined. It is not possible to measure directly the size of the defect in the plane perpendicular to the crystal surface. To obtain this measurement the material must be inspected from opposite faces and the difference in the distance from each face to the defect noted. Or if the form or shape of the material is such that it can be inspected from the side, the size of the flaw in this direction can be determined.

The method is best suited for detecting deep-seated defects which present a reflecting surface to the beam. It is not particularly adaptable for the detection of surface or near-surface defects which are located within approximately 1 in. of the contact



Schematic sketch of reflection and through-transmission methods of supersonic inspection, showing the principles of operation.

surface. Sometimes where the nature of the material of the variables present are such as to prevent good transmission of the sound beam, no backwall pattern is obtained. Defects which offer no reflecting surfaces to the sound waves cannot be detected. For example, small shrinkage pin holes in some cases do not provide defect reflection patterns.

The size of defect reflection will be dependent upon the amount of the transmitted sound waves which is intercepted by the defect area perpendicular to the supersonic beam. It is often possible for the trained operator to determine the type defect after scanning the sweep line indications. This ability comes with practice. With training an operator will be able to distinguish readily between good and bad material. In practice, he will generally use one of two methods for testing. With the first, a preliminary knowledge of the standards required will have been obtained. The Reflectoscope is then adjusted to a given sensitivity, and only those discontinuities equal to or greater than tolerance will be indicated on the oscilloscope. With the second method, for experimental testing, a known sample is explored and the sensitivity of the instrument calibrated to a set of standards in this fashion.

The reflection method has already been widely used for the inspection of such items as billets and booms, forged products such as steel axles and stainless steel rotor blanks, tool and die steel stock, and aluminum extrusions. It has met with considerable success in the inspection of welds for detecting fine defects such as hair-line cracks and fusion line flaws. Portability of the equipment permits its use for trouble-shooting jobs around the plant.

Through-Transmission Method

When a beam of sound energy is directed through a piece of material some of this energy is dissipated in going through the material. If a discontinuity such as a crack is also encountered during the passage, the energy pattern is further weakened. Thus differences in addition to the normal losses between the energy of the sound wave entering one side of the material and that picked up on the other side, indicate the presence of discontinuities in the specimen. This is the principle of the through-transmission method

Inspecting steel billets by the supersonic reflection method. The scanning disc in front of the operator reveals the presence of flaws. (Courtesy: Sperry Products, Inc.)

used in the equipment developed by the Brush Development Co.

The equipment, known as the Hypersonic Analyzer, consists of the following essential parts:

1) An electronic supersonic generator which creates a signal;

2) A Piezoelectric crystal transducer which converts the supersonic signal into mechanical supersonic energy which is transmitted through the material under test;

3) A Piezoelectric crystal transducer which serves as a receiver of the transmitted sound and converts the mechanical energy into an electrical signal;

4) An electronic amplifier which increases the output of the receiver-transducer; and,

5) An indicating device for signalling the presence of flaws.

The frequency of the sound waves used in this equipment is normally in the region between 50 and 1000 kilocycles per sec. In operation the hypersonic analyzer is adjusted for the particular type of material being inspected. A critical set of radiation frequencies is selected so that the resultant sound beams through the material are highly modified by any given type of flaw in any given material.

Since fluids such as water and oil give better coupling between the transmitter, the material, and the receiver, at supersonic frequencies, the material to be inspected is usually placed in a liquid which is used as the transmitting medium. In some applications air or other gases may be used; the choice of the medium depends upon the material being examined and whether or not it may be exposed to a particular medium without damage.

After the piece is placed in the liquid the crystal transmitter is then energized and sends supersonic waves through the material. These waves are picked up by the crystal receiver on the opposite side, transformed to electrical energy, and amplified. A constant result is registered until flaws are encountered. The detection of flaws can be indicated by a meter or any signalling device desired.

One, or a series of transmitting and receiving crystals may be employed depending on the area to be inspected. In some cases six channel units have been designed to inspect a wide area. Since the

A typical set-up using the through-transmission method. Here laminated clutch disks are being examined for flaws in the bond. They are passed between the sending and receiving crystals which are immersed in a liquid bath. (Courtesy: Sperry Products, Inc.)

transmitting and receiving crystals must be kept parallel and opposite each other, the crystal transducers remain stationary and the material to be inspected is moved between them. Automatic set-ups can be made in which the material is run through at a high speed and a signalling arrangement such as a light or bell or a marker employed to indicate when defects are encountered.

Applications of the Transmission Method

Most metallic materials and plastics can be inspected by the supersonic transmission method. However, heterogeneous materials (like concrete) cannot be efficiently inspected; their irregular or nonuniform internal structure tend to modify the transmitted sound beam even more than do the discontinuities which might be present. The present equipment is capable of examining thicknesses up to 5 in. thick, while thicknesses down to 0.001-in. can be handled satisfactorily.

The forms or shapes inspected must have a uniform cross-section over the area covered by the crystals so that the sound beam goes through the same thickness of material at all points. The pieces being inspected must also have axial continuity; that is, the same cross-sectional thickness must be presented to the crystals as the material is run through for inspection. It can be seen from this that the method is most applicable to shapes and forms having a constant cross-section such as those obtained by means of rolling and extruding.

The surface conditions necessary for satisfactory inspection depend to a large extent on whether or not a liquid bath is used for establishing contact between the crystals and material being examined. If a liquid or gas bath is used the surface texture of the material need only be the equivalent of a rough machined or sawed surface. However, when the crystals make direct contact using only a film of oil as the coupling agent, the surface must be much smoother for satisfactory results.

Flat surfaces are the most practicable for inspection purposes, but objects with curved surfaces can be inspected as long as the surfaces between the transmitting and receiving crystals are parallel.

This method of supersonic inspection detects flaws associated with two physical properties of the material: a change in the total mass or density, and a change in stiffness or modulus of elasticity. The method does not tell which property is changed but indicates that either one or both have changed.

The minimum change in density which can be practically detected is a 0.001-in. internal air film. The smallest change in modulus of elasticity of steel which can be detected is 2%. Because this method is sensitive to changes in modouls of elasticity, very thin slits or cracks can be detected. This type of flaw is one where the change in total mass is negligible, but at the separation junction the effective modulus is obviously small since the material is already separated. This sonic method will detect flaws of this type as small as 0.001 in.

This slit type of flaw occurs frequently in rolled

sheet materials, many times as laminations. Separations in sandwich type construction of sheet materials at the bond is another example of this type of flaw. All the other common types of gross defects which involve a change in the density or stiffness of the material—such as porosity, inclusions and segregations, shrinkage voids—can be picked up.

Since the penetrating sound beam is sensitive to many types of discontinuities it is not possible to tell exactly which type of defect is present when a flaw is detected. Generally the Hypersonic Analyzer is applied to jobs which involve the detection of a specific type of defect; then, as mentioned previously, a critical set of radiation frequencies and electro-acoustic designs is selected so that the sound beam is affected by this given type of discontinuity.

Thus far it has been found that the method is not adaptable to the inspection of welds. This is due to the nonuniformity of the weld structure boundary which modifies the sound beam even more than any defects which might be present. Thus, the indications received from weld structure irregularities are stronger and obliterate those created by the flaws.

It is obvious that the position of flaws is determined by noting the location of the crystal on the piece when a flaw is detected. Discontinuities with a lateral projected area as small as 1/16 in. can be accurately located. The outline and size of flaws can be traced, if desired, by moving the material around and noting by the signalling device each time the sound beam is affected. It is not possible, however, to determine where in the cross-section a flaw is located, nor the depth of the flaw.

From the foregoing discussion it is evident that the transmission method of supersonic inspection is most suitable in applications involving continuous production lines of material with a uniform cross-section. Typical applications are inspection of products produced by rolling and extruding such as metal sheets and strip, and plastic products. The method has wide application in manufacturing processes where bonding of materials is employed, such as safety glass, tire plies, bonded metal strips, clad metals, and sandwich plastic materials.

Another advantage to production set-ups is its high rate of inspection. Since the sound frequencies used are high, the relay action is fast and material can flow through at a high speed. For example, sheet steel can be inspected at the rate of 2600 ft. per min.

It is apparent that the inspection method is primarily a qualitative one in that it is a "stop or go" method. It detects the existence of flaws, but does not indicate the exact type and nature, nor the location and size in depth of defects.

Development work is still in progress on this supersonic method and it is probable that many refinements will result in the future. Besides the particular equipment described here, a machine operating on the transmission principle also, has been recently developed by Sperry Products Co.

Supersonics vs. Radiography

Supersonic methods of inspection will not replace radiography, but rather will supplement it. Each has its particular capabilities and limitations which in the long run will determine for which application each is best suited.

Radiography at present is limited to a penetration of around 6 or 7 in. with million volt equipment. Although the new multimillion volt Betatrons are capable of inspecting section thicknesses up to around 12 in., radiography will probably never be able to approach penetrations on the order of 10 to 20 ft. in steel now possible by the supersonic reflection method.

In the range of thickness where radiography can be used, supersonics compares favorably in a number of respects. Both the transmission and reflection methods are more sensitive and can reveal the presence of very fine defects such as laminations and hairline cracks which radiography cannot.

With the reflection method it is possible to determine accurately where in the cross-section the defects lie, and in most cases the size in depth of defects. Using radiography it is not possible to do this except by special means (stereoscopy).

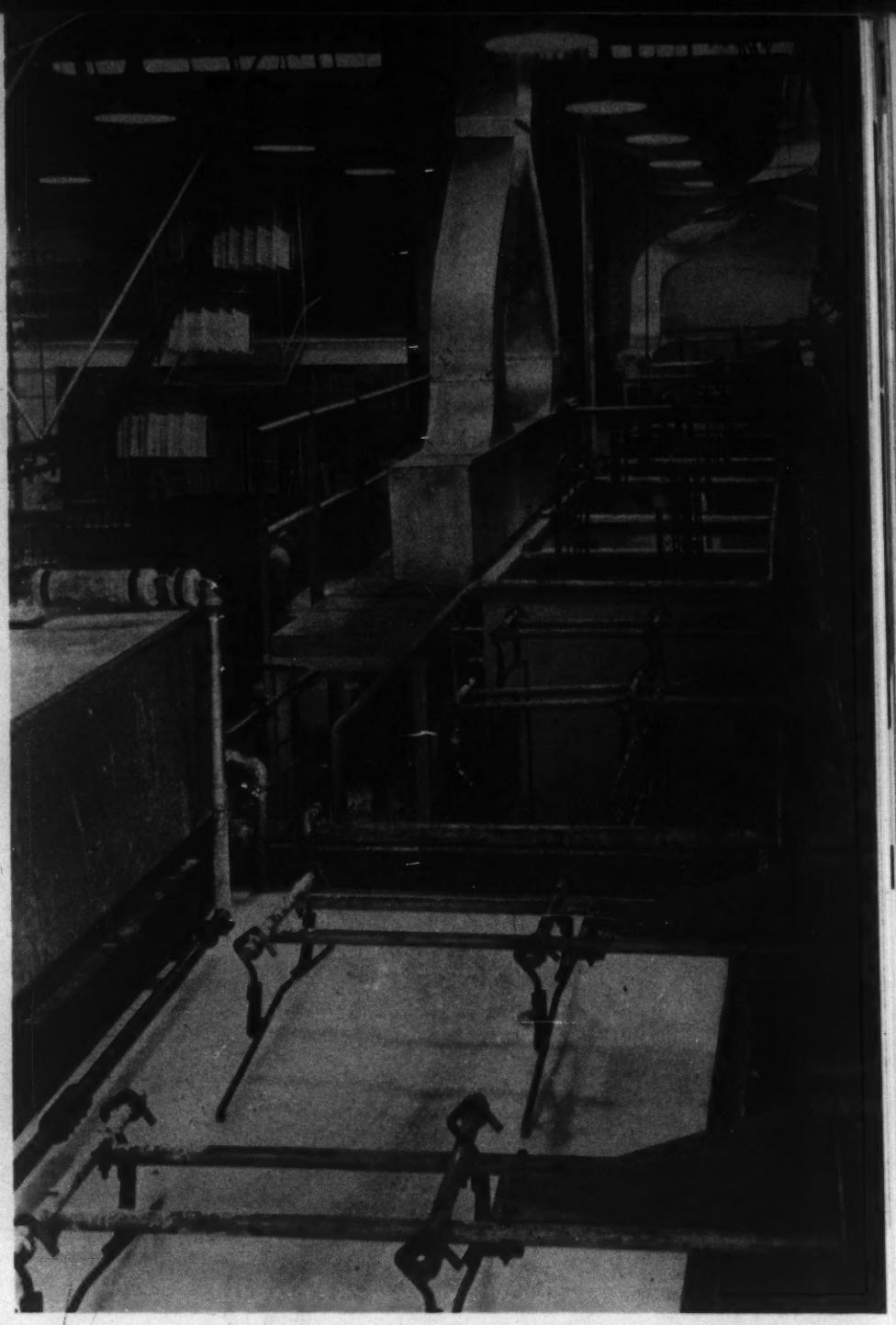
Although no comparative cost figures have been obtained, it appears that the supersonic methods have lower operating costs than radiography if no permanent record of results is required. In such applications, film and film processing costs are saved. However, where permanent records of results are needed, showing the type and size of defect, photographs or some other means are needed to record the findings. Probably here radiography and supersonics would compare very closely.

On the other hand, there are several respects in which radiography has the advantage over supersonics. There are practically no limitations to the shapes and forms of materials which can be X-rayed; supersonic methods are restricted to the inspection of parts or shapes with parallel walls in the areas being inspected. Uniform cross-sections and flat smooth surfaces are required for optimum results with supersonics. These limitations do not apply to radiography.

Radiographic results are more easily interpreted from the standpoint of defect identification than are supersonic indications of flaws. With sufficient experience, it is possible to identify some types of defects using the reflection method, but the identification is not as clear-cut as the shadow-pictures obtained by radiography. It is quite probable, however, that with additional development work in supersonic inspection, methods of flaw identification will be greatly improved.

Supersonics constitutes a new field of non-destructive testing. It should be pointed out that every new testing method must go through a trial period during which time correlation of test results with actual service performance must be pursued. This period of development has just begun for supersonic inspection methods and much work lies ahead. Its ultimate success as a materials inspection tool depends largely on this development period to work out means of accurately interpreting test observations and correlating them with service results.

Several years of research and engineering were spent in planning and putting into service this extremely modern, efficient finishing system.



1 This fully automatic electroplating machine is, roughly, 70-ft. long, 15-ft. wide and 17-ft. high. It utilizes a vertical lift of nearly 7 ft. at the 12 automatic transfer points. Three operators are required as against 12 persons to man a similar still tank setup.

Resin Finishing of Refrigerator Parts—

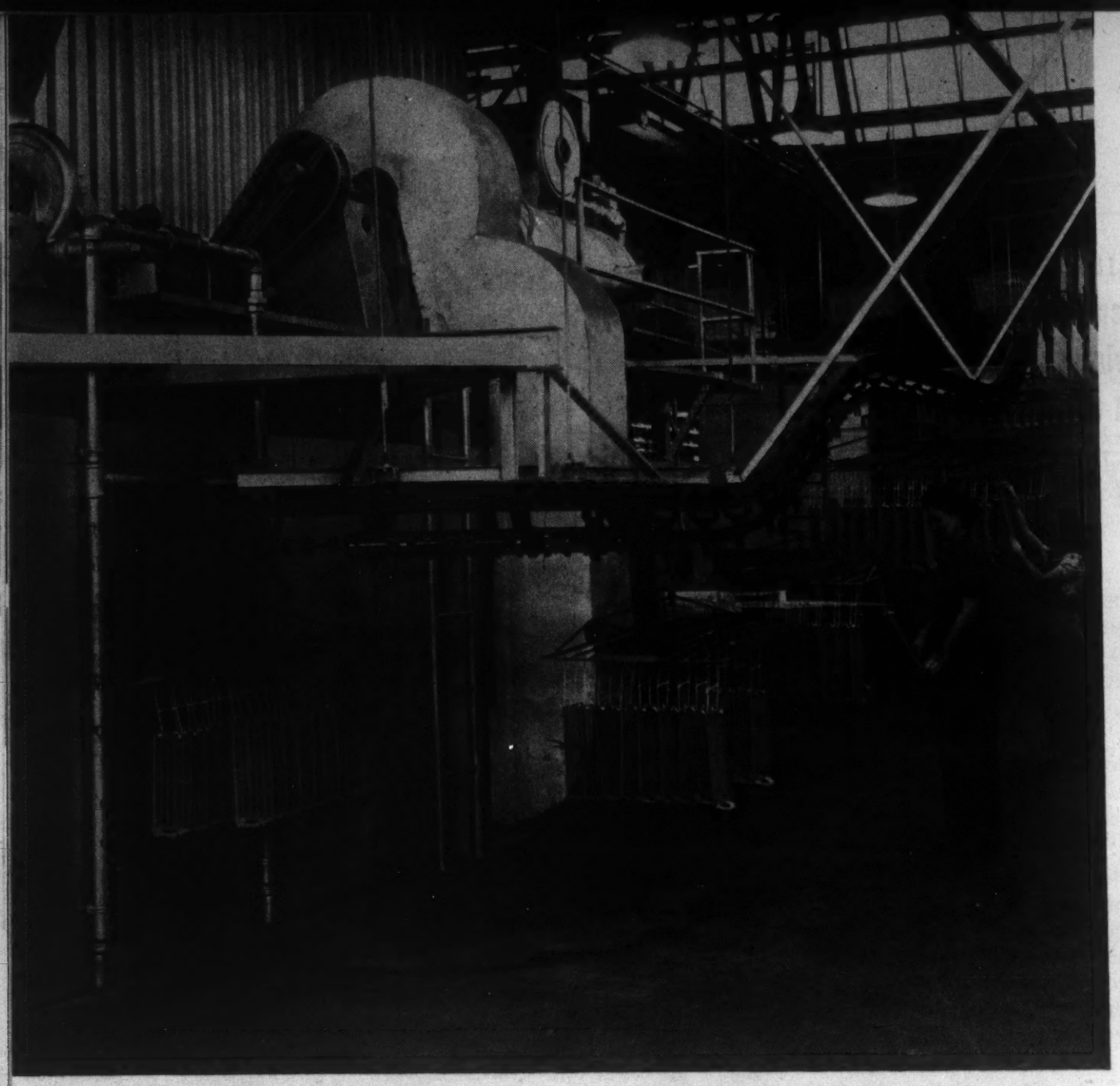
A PICTORIAL STORY

IMMEDIATELY AFTER V-J DAY Servel, Inc., Evansville, Ind., started work on plans which had been developed during the previous few years for a completely automatic system for the plastic coating of refrigerator shelves. The complete process consists of four stages, namely: zinc electroplating, coating with a phosphate bonding material, dip coats of primer and enamel, and, finally, electrostatic detearing.

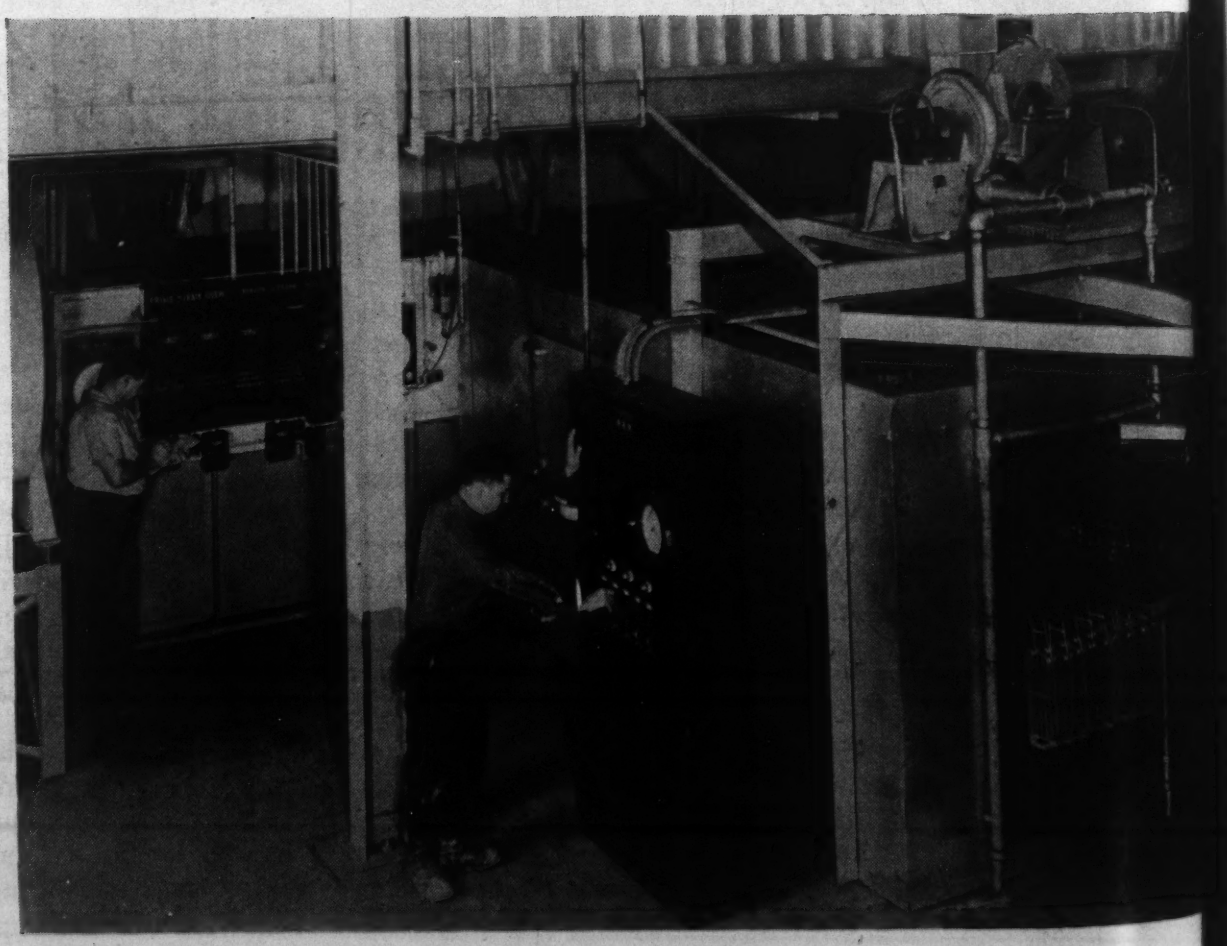
The materials and processes employed are adjudged highly satisfactory not only in the physical act of finishing the parts, but in the final results obtained. Characteristics of the finished coating such as moisture resistance, abrasion resistance, flexibility, film thickness, gloss and color retention are considered superior.

Among the tests finished products must pass are thickness and Weatherometer. The plastic coating—an alkyd-urea formaldehyde material—must withstand 1000 hr. at 100% relative humidity at 110 F controlled temperature without any evidence of breakdown. Specifications call for a minimum of 1000 wear cycles of a weight equal to a filled pint bottle of milk without wearing through the top plastic coat. In addition, the finish must withstand a 180-deg. bend on a ⅜-in. mandrel without cracking, flaking or any other breakdown. Minimum thickness is 0.0008-in. Gloss must be minimum 85 on a 60-deg. glossmeter and the finish can show no change in color after storing test panels in a blackout cabinet for 90 days.

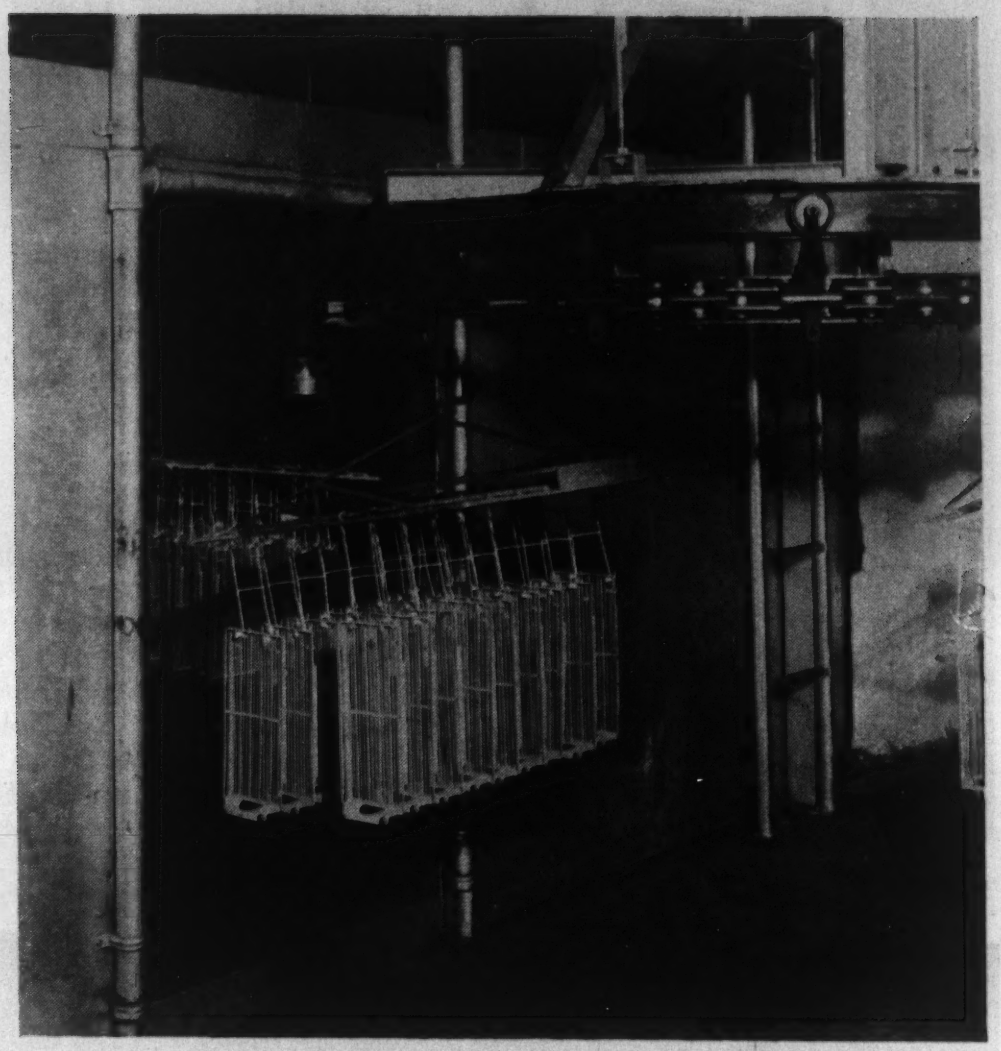
—Gerald Eldridge Stedman



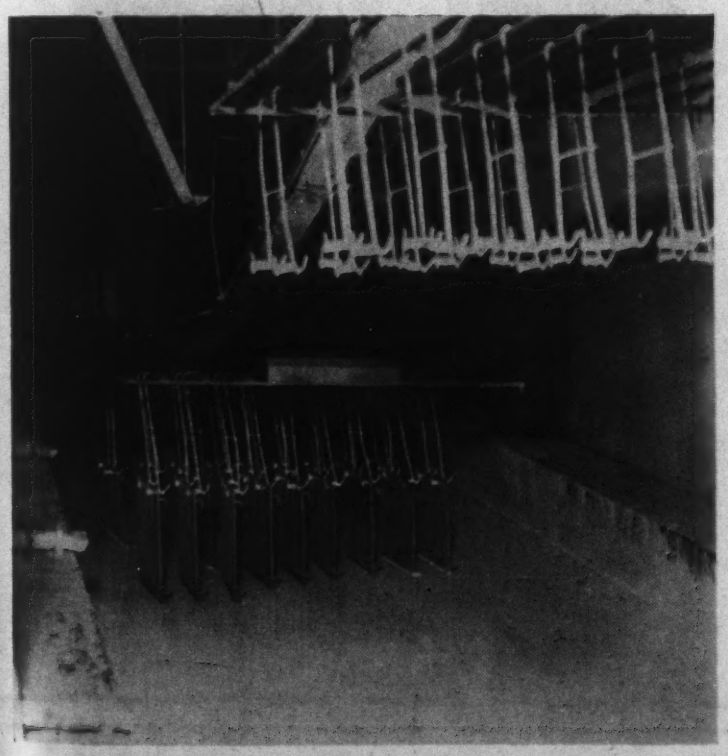
2 The 4-in. monorail conveyor system is 1,000-ft. in length and moves at a speed of 6 ft. per min. Trolleys have 16-in. centers with master hangers on 32-in. centers.



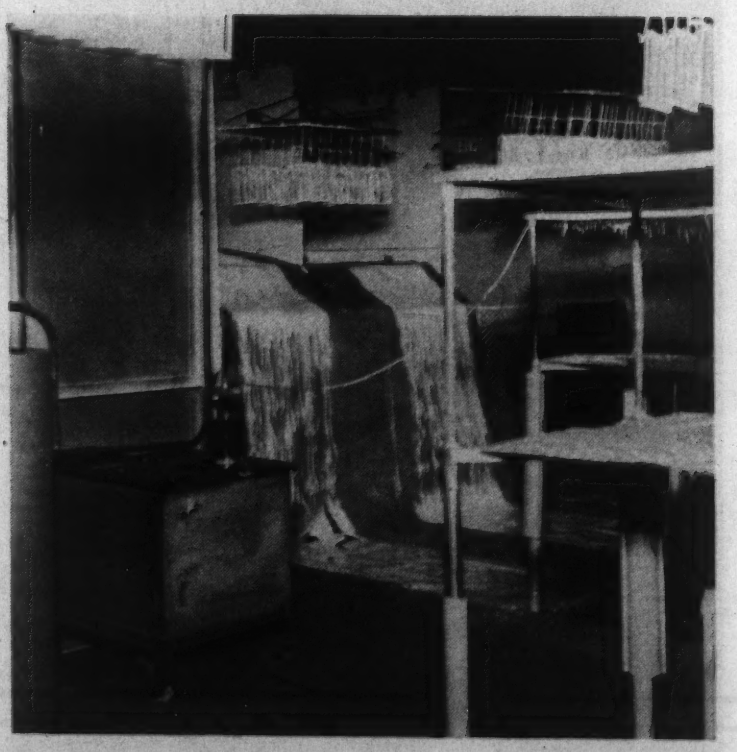
4 Two curing ovens are used, one for each coat of resin applied. They are heated with 175-lb. steam passing through coils in the duct system. The primary coat is baked at 320 F and the final coat at 300 F. The first cooling tunnel reduces temperature of the shelves from 400 F to 110 F in 7 min.; the second from 320 F to 110 F in 10 min.



3 Bonderized food shelves are given a heat soak to release entrapped gases before the first dip. The oven is heated by a low-pressure direct gas-fired heater and operates at 350 F. Uniformity is gained by recirculating fan and positive exhaust.



5 A dip in the monorail system lowers the shelves into the coating material which is of the alkyd-urea formaldehyde type. A carefully determined rate of withdrawal from the tank was necessary to prevent reflow and excessively heavy coats.



6 The electrostatic detearing equipment power pack converts 220-v. a.c. current to an 85,000-v. static field. The field is controlled by the size of the wire grid to which the power pack is connected. The effective range for detearing is 8 to 10 in. above the grid which is mounted on insulated hydraulic cylinders below the conveyor line.

7 Parts ranging in length from ¾-in. to 30-in. long pass over the detearing grids, so it is necessary to accurately position the grids. Thus, central control is provided to actuate the hydraulic cylinders which raise and lower the grids.

8 Infrequently the static field above the grids will arc across to the ware suspended on the grounded conveyor line. An air exhaust system over each grid maintains an air flow velocity of 100 ft. per min. With such dilution it is improbable that a sufficiently high solvent concentration can surround the ware as to create danger of igniting.

There is no one die steel for all die casting dies as the type of alloy cast and the length of run make varying demands upon the steel employed.

Steels for Die Casting Die Blocks

by JAMES L. ERICKSON

BECAUSE OF THE MANNER in which die castings are made, the high speeds of production pressures and the temperatures involved, steels employed to make die casting dies must possess certain characteristics such as:

(a) the ability to withstand thermal fatigue impact shock;
(b) the ability to resist cleavage cracking, or cracking due to sudden changes in temperature, *i.e.*, thermal stresses;
(c) the ability to remain hard at elevated temperatures;
(d) the ability to resist the solvent action of incoming molten metal;
(e) sufficient strength to resist working stresses (as opposed to thermal stresses) without deforming;
(f) stability during heat treatment;
(g) cleanliness, and
(h) machinability.

The degree to which a steel chosen for a given die casting die should possess the first five of these characteristics depends upon three principal factors: (1) the temperature of the alloy to be injected into the die cavity, (2) the number of casting cycles it will be required to survive, and (3) the size and shape of the part to be die cast. The higher the temperature of the metal injected and the greater the number of casting cycles, the greater is the need for the steel to possess these first five characteristics to a high degree.

The die caster in selecting a steel for a given die must consider carefully each of these three factors because those steels which possess the necessary characteristics to the greatest extent are the most highly alloyed and, therefore, the most costly. The need for careful analysis becomes even clearer when one considers the fact that the steels offered for die casting dies vary in price between twelve and ninety cents per lb.—and that certain dies may call for as many as 500 lb. of steel.

The necessary physical properties are: (a) high hardness at elevated temperature, (b) high impact strength at elevated temperatures, (c) high fatigue strength at elevated temperatures, (d) low coefficient of thermal expansion, (e) high damping capacity (this is questioned by some because the frequency of stress repetition is not high in the case of die casting dies), and (f) high modulus of elasticity.

The die casting industry dates back to 1849, when Sturgiss patented the first die casting machine for producing tin base alloy die castings. Die materials at this date were satisfactory enough to make possible die casting the low melting point alloys. Soon afterward zinc alloys were introduced and despite their slightly higher melting point, the existing die materials proved satisfactory for the comparatively short runs then required. Aluminum as a die castable material made its appearance later. Its higher melting point brought about the search for better steels. At the same time orders for zinc base alloy die castings called for larger numbers from individual dies. It was found that steels suitable for short casting cycles, or *short runs,* in zinc base alloys were not suitable for long casting cycles, or *long runs.* By the time the copper base alloys were introduced, the die steels were considerably improved. The demands upon die steels, however, continued to rise.

Today, as a result of a close cooperation between certain die casters and certain steel concerns, much valuable progress has been achieved. Nevertheless, there is still an enormous need for die materials that will make possible long runs in copper base alloy die casting, and, for that matter, long runs (over 500,000) in aluminum base alloys.

Steels for Lead and Tin Base Alloys

Inexpensive low carbon steels and low alloy steels are universally employed today to prepare dies for die casting the low melting point lead and tin base alloys. Reasons for this are: (1) the thermal shock suffered by dies used to die cast the low melting point alloys is insufficient to engender heat checking even when the runs are long because of the low temperature of these alloys at the time they flow into the die cavity, and (2) a low injection pressure is employed when making die castings of these alloys, the velocity of the incoming molten metal stream therefore is small as compared with the velocities encountered in die casting the higher melting point alloys where high pressures are employed.

Table I—Steels for Die Casting Dies for Tin and Lead Base Die Casting Alloys*

Length of Run**	C	Mn	Si	Ni	Cr	V	W	Mo	Others
Carbon Steels									
S-L	0.20-0.50								
Manganese Steels									
S-L	0.40	0.40							
1% Chromium-Manganese Steels									
S-L	0.50	0.80	0.30		0.90				
S-L	0.35	0.80	0.30		1.00				
1% Chromium-Manganese-Vanadium Steels									
S-L	0.50	0.70	0.30		1.00	0.20			
S-L	0.50	0.75	0.30		1.00	0.15			
1% Chromium-Manganese-Nickel Steels									
S-L	0.45	0.70		1.25	0.80				
1% Chromium-Manganese-Molybdenum Steels									
S-L	0.54	0.65			0.80			0.40	
S-L	0.40	0.75			1.00			0.20	
S-L	0.30	0.50			1.20			0.50	
1% Chromium-Manganese-Molybdenum-Silver Steel									
S-L	0.40	0.75			1.00			0.20	Ag-0.15
1% Chromium-Manganese-Molybdenum-Lead Steels									
S-L	0.40	0.75			1.00			0.20	Pb-0.10

* The various chemical compositions for the steels listed in this and subsequent tables are typical of individual steels offered at the present time by individual steel companies. Each typical composition listed represents a particular steel offered for the preparation of die casting dies. Trade names of each of these steels have been omitted for obvious reasons.

** S—Short; L—Long.

A low carbon steel (0.20-0.50% C) and a chromium-manganese steel (0.50% C, 0.80% Mn, 0.90% Cr) are widely used today for dies for die casting lead and tin base alloys.

The low carbon type steel is generally used in the unheat treated condition, while the chromium-manganese type steel is most frequently used in the normalized condition.

Several variations of the chromium-manganese type steel are at present offered, Table 1. Most frequent alloying elements to this type of steel are molybdenum and vanadium. Occasionally silver, aluminum and nickel are also added.

Steels for Zinc Base Alloys

The molten metal temperature involved in zinc base alloy die casting are comparatively low, *i.e.,* around 800 F. A die steel hardened to Brinell of between 200 and 250 has been found satisfactory for short and medium long runs of zinc base alloys. The die steel is usually hardened to the required Brinell hardness before machining and then used to make die castings without further heat treatment. Long runs however, call for heat treatment after machining.

For short runs in zinc base alloys, one steel company recommends a low carbon steel used for the low melting point alloys of lead and tin. Likewise, the same type of 1% chromium-manganese steel recommended for the low melting point alloys is recommended for dies to make zinc base alloy die castings, *viz.,* the 0.50-0.80% manganese, 0.80-1.20% chromium with the addition of molybdenum or vanadium. Another steel company recommends a 0.70% vanadium steel with the addition of 0.20% tungsten.

Silver and lead are both present in the 0.40% carbon, 0.75% manganese, 1.00% chromium, 0.20% molybdenum, 0.10% lead steel. These elements are added to permit machining of the dies at high hardness values—thus making possible the use of the dies without a separate hardening operation after machining.

One die caster claims that with a steel containing 0.40% carbon and 0.80% chromium, heat treated to a Brinell hardness of 400 it is possible to make 100,000 die casting cycles before heat checking takes place. He adds, however, that dies of this steel, because of being oil quenched in heat treatment, are subject to considerable distortion and dimensional change.

Steels offered for long runs in zinc base alloys vary considerably in composition. For example, one concern suggests that a 0.75% manganese, 0.80% chromium steel alloy with the addition of 0.25% vanadium, while another steel company recommends a higher chromium content alloy such as the 2.00% chromium, 0.20% vanadium alloy and the 0.60% manganese, 2.00% chromium alloy. Still higher chromium content steels, *viz.,* the 0.40% manganese, 0.90% silicon, 5.00% chromium steel and the 0.40% manganese, 5.00% chromium, 1.50% tungsten steel with the possible addition of 1.25-1.75% molybdenum and/or 0.80-1.20% silicon are required if the zinc run is very long (greater than 100,000-500,000).

For very long runs, one steel company offers a 5.00% chromium, 1.50% molybdenum steel with the addition of 0.15% silver. It is claimed that the presence of the silver so increases machinability that this steel when prehardened and tempered to approximately 65-70 Scleroscope can be readily machined.

Steels for Aluminum and Magnesium Base Alloys

In order for a steel to be considered satisfactory for the preparation of dies for making aluminum and/or magnesium base alloy die castings, it must be capable of being heat treated to a minimum hardness of 400 Brinell after tempering at a temperature of 1100 F, because both aluminum and magnesium base alloys are cast within the temperature range 1100-1300 F, and if the die steel cannot stand this draw, it will soon soften in service. For a steel to be suitable, it must also be inherently resistant to sealing after heat treatment in order to reduce hand polishing operations.

One die steel offered contains only 0.90% silicon and 5.00% chromium. This particular steel is not, however, generally used. Another steel containing 4.75% chromium, 1.40% molybdenum and 1.40% tungsten has better high temperature properties. Still another die steel contains 5.00% chromium, 0.30% vanadium and 1.25% tungsten. This steel is used frequently by some die casters who report that it behaves well in service.

On the whole the majority of steels suggested by the steel producers for dies for the light metals are variations of a steel having the approximate composition: 0.35% carbon, 1.00% silicon, 5.00% chromium, 1.25% tungsten and 1.25% molybdenum. This basic type of steel has over a period of years proven satisfactory for the light metals. Indeed, this type of steel is widely employed by die casters today.

This 5.00% chromium type steel was originally developed for the die casters who were anxious to obtain an air hardening steel that would harden from a low temperature and which would neither scale or distort when air cooled. This type of steel is able to withstand alternate heating and cooling without premature heat checking and is able to resist the erosive action of molten aluminum or magnesium alloys to a high degree. It has extremely high toughness and a pronounced secondary hardness at and about 1000 F. Thus, it is able to withstand considerable heat without softening, as well as the mechanical shock incurred when the dies are closed and thermal shock resulting from alternate heating and cooling.

Some of the variations on this type steel do not contain tungsten while others contain the addition of vanadium.

A few typical analyses of those steels which do not contain tungsten but which contain up to 0.50% vanadium as an alloying element are (for short runs): (1) 0.40% carbon, 0.40% manganese, 1.00% silicon, 5.00% chromium, 0.35% vanadium, 1.35% molybdenum, (2) 0.35% carbon, 1.00% silicon, 5.00% chromium, 0.020% vanadium, 1.75% molybdenum, (3) 0.40% carbon, 0.30% manganese, 1.00% silicon, 5.50% chromium, 0.40% vanadium, 0.85% molybdenum, and (4) 0.30% carbon, 0.60% manganese, 0.90% silicon, 5.00% chromium, 0.25% vanadium, 1.00% molybdenum, and (for long runs): (1) 0.30% carbon, 1.00% silicon, 5.00% chromium, 0.25% vanadium, 1.75% molybdenum, (2) 0.40% carbon, 0.40% manganese, 1.00% silicon, 5.00% chromium, 0.40% vanadium, 1.40% molybdenum, (3) 0.40% carbon, 0.40% manganese, 1.05% silicon, 5.00% chromium, 0.35% vanadium, 1.35% molybdenum, and (4) 0.40% carbon, 0.30% manganese, 1.00% silicon, 5.40% chromium, 0.40% vanadium, 0.85% molybdenum.

The 0.40% carbon, 0.30% manganese, 1.00% silicon, 5.40% chromium, 0.40% vanadium, 0.85% molybdenum type steel possesses excellent heat and wear resisting properties. At high temperatures this steel retains good physical properties, thus reducing die wash and maintaining a high resistance to heat checking. It is generally tempered well above the temperature reached by the die blocks as a whole during the die casting operation. It will maintain its hardness at elevated temperatures and thus will give long die life. This steel was originally developed as a die casting die steel.

Steels of the same type containing a larger percentage of vanadium and suggested for short runs in aluminum are: 0.34% carbon, 0.45% manganese, 1.00% silicon, 5.00% chromium, 0.75% vanadium, 1.40% molybdenum, and 0.40% carbon, 1.00% silicon, 5.50% chromium, 1.00% vanadium, 1.10% molybdenum.

These steels generally give 200,000 to 300,000 shots before they become heat checked to the point where castings made from them are rejectionable. The makers of these steels claim that over a period of years and with cooperation of die casters it has been discovered that the 5% chromium type steel without tungsten and with high vanadium possesses greater toughness than when the tungsten is present and the percentage of vanadium is lower. The removal of tungsten does not cause a drop in high temperature strength or wear resistance, and some advantage in machinability on intricate dies is obtained.

One steel not containing either vanadium or tungsten has a composition 0.90% silicon, 4.75% chromium, 1.30% molybdenum. This steel is in common use. It possesses a coefficient of linear expansion equal to 7.1×10^{-6} up to 1100 F, has a maximum safe working temperature of 1000 F, has excellent resistance to fatigue at high temperatures, and has a tensile yield strength of 155,000 p.s.i. and an ultimate tensile strength of 195,000 p.s.i. at 1000 F. It is heat treated to between 44 and 56 Rockwell C.

Dies made from the 0.40% carbon, 1.00% silicon, 5.50% chromium, 1.00% vanadium, 1.00% molybdenum type steel can be hardened readily to give between 444 to 460 Brinell as desired. This steel is of the air hardening type and does not distort during heat treatment. As many as 200,000 to 300,000 shots may be made as an average on dies of this type steel. A similar type of steel containing only the addition of tungsten and a lower vanadium content has been found by some die casters to be less satisfactory since it is not as tough as the steel without the tungsten and higher vanadium percentage. Toughness is needed

Table II—Steels for Dies for Zinc Base Alloy Die Casting*

Run	C	Mn	Si	Ni	Cr	V	W	Mo	Others
Carbon Steels									
S	0.20-0.50								
Manganese Steels									
S	0.40	0.40							
Tungsten-Vanadium Steels									
S	0.55					0.70	0.20		
1% Chromium-Manganese Steels									
S-L	0.35	0.80	0.30		1.00				
S	0.50	0.80	0.30		0.90				
1% Chromium-Manganese-Vanadium Steels									
S	0.50	0.75			1.00	0.15			
S-L	0.45	0.70	0.25		1.00	0.25			
S	0.50	0.65			0.90	0.20			
L	0.50	0.65	0.20		1.00	0.20			
1% Chromium-Manganese-Nickel Steels									
S	0.45	0.70		1.25	0.80				
1% Chromium-Manganese-Molybenum Steels									
S-L	0.54	0.65	0.25		0.80			0.40	
S	0.35	0.80	0.30		0.80			0.30	
S	0.40	0.65	0.25		1.00			0.20	
S	0.40	0.75	0.25		1.00			0.20	
L	0.30	0.75	0.50		0.80			0.25	
L	0.42	0.65	0.25		1.00			0.20	
1% Chromium-Manganese-Molybdenum Nickel Steels									
S	0.50	0.80	0.25	1.00	0.80			0.20	
1% Chromium-Manganese-Molybdenum-Silver Steels									
S	0.40	0.75			1.00			0.20	0.15 Ag
1% Chromium-Manganese-Molybdenum-Aluminum Steels									
S	0.40	0.50	0.25		1.20			0.50	1.20 Al
1% Chromium-Manganese-Molybdenum-Lead Steels									
S	0.40	0.75	0.25		1.00			0.20	0.10 Pb
2% Chromium-Vanadium Steel									
L	0.40	0.20	0.25		2.00	0.20			
2% Chromium-Manganese-Vanadium Steel									
L	0.45	0.60			2.25	0.20			
5% Chromium-Silicon Steel									
L	0.30	0.30	0.90		4.75				
5% Chromium-Tungsten Steel									
L	0.30	0.30	0.30		4.75		1.30		
5% Chromium-Molybdenum-Silicon-Vanadium Steel									
L	0.30	0.30	1.00		5.50	1.00		1.10	
S-L	0.40	0.40	1.00			0.50		0.90	
5% Chromium-Tungsten-Molybdenum-Silicon Steel									
L	0.35	0.30	1.00		5.00		1.15	1.15	
L	0.35	0.30	1.00		5.00		1.25	1.50	
5% Chromium-Molybdenum-Silver Steel									
L	0.35	0.30	0.25		5.00			1.50	0.15 Ag
Tungsten-Chromium-Silicon-Cobalt									
S-L	0.40	0.30	1.00		5.25		4.50		0.50 max. Co

* See Footnote to Table I.

to prevent die erosion. Often this steel is used by die casters in the unheat treated condition as the steel can be obtained in the annealed condition and as such has sufficient pressure resistance to stand the high pressures involved without any tendency to shrink, heat check, or wash out.

Of the 5.00% chromium type steels that do contain tungsten there are two groups, those containing vanadium and those not containing vanadium. Of the latter group the most frequently employed are: (1) 0.35% carbon, 0.30% manganese, 1.00% silicon, 5.00% chromium, 1.15% tungsten, 1.15% molybdenum; (2) 0.35% carbon, 1.00% silicon, 5.00% chromium, 1.25% tungsten, 1.50% molybdenum; (3) 0.35% carbon, 0.30% manganese, 1.00% silicon, 5.00% chromium, 1.15% tungsten, 1.15% molybdenum; and (4) 0.35% carbon, 0.35% manganese, 1.00% silicon, 5.25% chromium, 1.25% tungsten, 1.50% molybdenum.

Good heat and wear resisting properties are found in the first of this group of steels. At high temperatures this steel retains good physical properties, thus reducing die wash and maintaining a high resistance to heat checking. This steel is drawn well above the temperature reached by the die blocks as a whole during die casting. It maintains its hardness at elevated temperatures and thus gives long service.

One steel contains 4.75% chromium, 1.40% tungsten, 1.40% molybdenum. This steel is in general use and possesses a good high temperature fatigue strength. It is commonly hardened to between 44 and 56 Rockwell C and possesses a coefficient of linear expansion of 7.1×10^{-6} at 1100 F. Its maximum safe working temperature is 1000 F. At 1000 F it has a tensile yield strength of 157,000 p.s.i. and an ultimate tensile strength of 197,000 p.s.i.

The typical tungsten containing 5.00% chromium type steels containing vanadium are: (1) 0.30% carbon, 0.90% silicon, 5.00% chromium, 0.25% vanadium, 1.00% tungsten, 1.00% molybdenum, (2) 0.35% carbon, 0.90% silicon, 5.00% chromium, 0.20% vanadium, 1.10% tungsten, 1.60% molybdenum, (3) 0.34% carbon, 0.35% manganese, 0.95% silicon, 4.75% chromium, 0.20% vanadium, 1.15% tungsten, 1.50% molybdenum, (4) 0.35% carbon, 1.00% silicon, 5.00% chromium, 0.20% vanadium, 1.30% tungsten, 1.75% molybdenum, (5) 0.35% carbon, 0.30% manganese, 1.00% silicon, 5.00% chromium, 0.20% vanadium, 1.50% tungsten. Each of these steels is recommended by a separate steel producer for short runs in light metals.

Steels of the same group as above offered for long runs are: (6) 0.35% carbon, 0.90% silicon, 5.00% chromium, 0.20% vanadium, 1.10% tungsten, 1.60% molybdenum, (7) 0.30% carbon, 1.00% silicon, 5.00% chromium, 0.25% vanadium, 1.30% tungsten, 1.75% molybdenum, (8) 0.35% carbon, 0.35% manganese, 0.95% silicon, 4.75% chromium, 0.20% vanadium, 1.15% tungsten, 1.45% molybdenum, (9) 0.35% carbon, 0.30% manganese, 1.00% silicon, 5.00% chromium, 0.20% vanadium, 1.50% tungsten, 1.65% molybdenum. Of these steels No. 1 possesses a maximum safe working temperature of 1300 F and is normally heat treated to between 35 and 56 Rockwell C. It has a coefficient of linear expansion of 7.2×10^{-6} from 0 to 1000 F and a coefficient of linear expansion of 7.4×10^{-6} within the temperature range 0 to 1500 F.

Of the above group, No. 7 steel is a general purpose die steel having good resistance to shock and to heat checking after repeated heating and cooling. Its physical properties at elevated temperatures compare favorably with some of the more expensive tungsten die steels.

Several tungsten hot work steels are suggested: these are of two types, those containing 4.00 to 5.00% tungsten and those containing 9.00 to 15.00% tungsten.

Of those containing 4.00 to 5.00% tungsten, one is of the composition 0.37% carbon, 1.30% chromium, 4.50% tungsten, 0.40% molybdenum; the other contains 0.35% carbon, 0.90% silicon, 0.50% nickel, 5.25% chromium, 0.25% vanadium, 4.50% tungsten, 0.50% molybdenum. The latter has added nickel and silicon.

Of the 9.00 to 10.00% tungsten alloys there are those containing the addition of vanadium, and those containing the addition of nickel, those with the addition of molybdenum, and those without any of these alloying elements. Steels without nickel are: 0.28% carbon, 3.20% chromium, 0.30% vanadium, 9.50% tungsten, 0.70% molybdenum. Those containing molybdenum are: (1) 0.35% carbon, 0.25% manganese, 0.25% silicon, 2.00% chromium, 0.50% vanadium, 9.25% tungsten, (2) 0.30% carbon, 0.20% manganese, 0.30% silicon, 3.50% chromium, 0.50% vanadium, 9.75% tungsten, (3) 0.35% carbon, 3.00% chromium, 0.50% vanadium, 10.00% tungsten. One steel containing nickel contains: 1.50 to 1.75% nickel, 2.50 to 3.00% chromium, 9.00 to 10.00% tungsten. Another contains: 0.30% carbon, 0.35% manganese, 2.75% chromium, 0.25% vanadium, 9.50% tungsten, 1.60% molybdenum.

Steel No. 1 in this group is hardened to 40 to 55 Rockwell C, has a safe working temperature of 1200 F, and a coefficient of linear expansion of 7.2×10^{-6} up to 1000 F. No. 2 is hardened to 40 to 55 Rockwell C and has a maximum safe working temperature of 1200 F. Its coefficient of linear expansion is 7.23×10^{-6} in the range of 0 to 1100 F.

Steels for Copper Base Alloys

Copper base alloy die casting is exceedingly demanding of steels. This is, of course, due to the fact that the temperature of the metal injected into the die cavity is anywhere from 1500 F for certain copper base alloys to as high as 1950 F for others.

A large number of steel companies offer their own particular compositions to die casters using the copper base alloys. Unfortunately, none of the steels offered is really satisfactory in the same sense as are the steels employed for lead and tin base alloy die casting. For example, none of the steels can be guaranteed to last a given number of injections.

Most successful die steels thus far developed are the hot work, tungsten steels containing between 8.00 and 15.00% tungsten.

Table III—Die Steels for Aluminum and Magnesium Alloy Die Casting

Length of Run	C	Mn	Si	Ni	Cr	V	W	Mo	Others
Chromium-Silicon Steel									
S	0.30	0.40	0.90		6.00				
Chromium-Tungsten-Molybdenum Steel									
					4.75		1.40	1.40	
Chromium-Tungsten-Vanadium Steel									
					5.00	0.30	1.25		
Chromium-Molybdenum-Silicon Steel									
S-L	0.30	0.30	0.90		4.75			1.30	
Chromium-Molybdenum-Silver Steel									
					5.00			1.50	0.15 Ag
Chromium-Molybdenum-Silicon-Vanadium Steels									
S	0.40	0.40	1.00		5.00	0.35		1.35	
S	0.35	0.30	1.00		5.00	0.20		1.75	
S	0.40	0.30	1.00		5.50	0.40		0.85	
S	0.30	0.60	0.90		5.00	0.25		1.00	
L	0.30	0.40	1.00		5.00	0.25		1.75	
L	0.40	0.40	1.00		5.00	0.40		1.40	
L	0.40	0.40	1.05		5.00	0.35		1.35	
S-L	0.40	0.30	1.00		5.40	0.40		0.85	
Chromium-Molybdenum-Silicon-Vanadium Steels									
S	0.34	0.45	1.00		5.00	0.75		1.40	
S	0.40		1.00		5.50	1.00		1.10	
Chromium-Tungsten-Molybdenum-Silicon Steels									
S	0.35	0.30	1.00		5.00		1.15	1.15	
S	0.35	0.30	1.00		5.00		1.25	1.50	
L	0.35	0.30	1.00		5.00		1.15	1.15	
L	0.35	0.35	1.00		5.25		1.25	1.50	
Chromium-Tungsten-Molybdenum-Vanadium-Silicon Steels									
S	0.30	0.30	0.90		5.00	0.25	1.00	1.00	
S	0.35	0.30	0.90		5.00	0.20	1.10	1.10	
S	0.34	0.35	0.95		4.75	0.20	1.15	1.50	
S	0.34	0.30	1.00		5.00	0.20	1.30	1.75	
S	0.35	0.30	1.00		5.00	0.20	1.50	1.60	
Chromium-Tungsten-Molybdenum-Silicon-Vanadium Steels									
S	0.35	0.35	0.90		5.00	0.20	1.10	1.60	
S	0.35	0.35	1.00		5.00	0.25	1.30	1.75	
S	0.35	0.35	0.95		4.75	0.20	1.15	1.45	
S	0.35	0.30	1.00		5.00	0.20	1.50	1.65	
Tungsten-Chromium-Molybdenum Steel									
S-L	0.37				1.30		4.50	0.40	
Tungsten-Chromium-Silicon-Nickel-Vanadium Steel									
L	0.35	0.35	0.90	0.50	5.25	0.25	4.50		
Tungsten-Chromium-Silicon-Cobalt									
S-L	0.40	0.30	0.90		5.25				0.50 max.
Tungsten-Chromium-Molybdenum-Vanadium Steel									
L	0.28	0.35	0.25		3.20	0.30	9.50	0.70	
Tungsten-Chromium-Vanadium Steels									
L	0.35	0.25	0.25		2.00	0.50	9.25		
L	0.30	0.20	0.30		3.50	0.50	9.75		
L	0.35				3.00	0.50	10.00		
Tungsten-Chromium-Nickel Steel									
L	0.30	0.35	0.25	1.80	2.75		9.50		
Tungsten-Chromium-Nickel-Molybdenum Steel									
L	0.30	0.35	0.25		2.75		9.50	1.60	

Table IV—Steels for Dies for Copper Base Alloy Die Casting

Length of Run	C	Mn	Si	Ni	Cr	V	W	Mo	Others
Chromium-Silicon Steel									
S	0.35		0.90		4.75				
Chromium-Tungsten Steel									
S	0.35		0.30		4.75		1.30		
Chromium-Tungsten-Molybdenum Steel									
S	0.35				4.75		1.40	1.40	
Chromium-Molybdenum-Silicon Steel									
S	0.35		0.90		4.75			1.30	
Tungsten-Chromium-Vanadium Steels (1.75-2.00% Cr)									
	0.35	0.25	0.25		2.00	0.50	9.25		
	0.35	0.20	0.20		1.75	0.35	11.00		
	0.40	0.30	0.30		2.00	0.40	11.50		
Tungsten-Chromium-Vanadium Steels (2.75-3.50% Cr)									
	0.30	0.30	0.30		3.25	0.30	9.00		
	0.30	0.25	0.30		3.25	0.50	9.00		
	0.30	0.25	0.30		3.57	0.50	9.00		
	0.30	0.25	0.30		3.30	0.50	9.25		
	0.30	0.25	0.30		3.25	0.40	9.50		
					3.50	1.00	9.50		
	0.35	0.25	0.30		3.50	0.50	9.75		
	0.30	0.30	0.30		3.10	0.35	10.00		
	0.40	0.30	0.30		3.25	0.40	11.00		
Tungsten-Chromium-Vanadium Steels									
	0.40	0.30	0.25		3.50	0.40	14.00		
	0.50	0.30	0.30		2.75	0.50	15.00		
	0.45	0.30	0.25		3.00	0.40	15.00		
	0.25	0.30	0.25		4.00	0.50	15.00		
	0.30	0.30	0.30		7.50	1.00	7.50		
	0.30	0.30	0.30		12.00	1.00	12.00		
	0.30	0.30	0.30		12.00	1.00	12.00		
Tungsten-Chromium-Cobalt Steel									
	0.30				1.50		4.00		5.00 Co
Tungsten-Chromium-Molybdenum									
					2.75		9.50	1.60	
Tungsten-Chromium-Nickel Steel									
				1.65	2.75		9.50		
Tungsten-Chromium-Nickel-Molybdenum Steel									
	0.30	0.35	0.30	1.65			9.50	0.30	

One steel company recommends the use of a 4.75% chromium, 1.25% tungsten steel for copper base alloy die casting. This steel exhibits satisfactory results for short runs.

A single 1.50% chromium, 4.00% tungsten, 5.00% cobalt alloy steel is recommended by one company. This steel has been successfully used by some die casters for many dies to cast copper base alloys. The interesting feature of this alloy steel is that it contains 5.00% cobalt.

Another steel has the composition 0.30 to 0.35% carbon, 0.90% silicon, 4.75% chromium. One die caster reports that unless only a very few (10,000 or less) die castings are required and the part is small and of simple design, it is unwise to risk the use of this steel.

Experience of the die casters preparing copper base alloy die castings has demonstrated the value of tungsten die steels having the approximate composition: 1.50 to 3.50% chromium, up to 0.50% vanadium, 9.00 to 11.00% tungsten. Many variations of this basic type steel are offered. These variations are the outgrowth of the findings of various die casters who have requested that the percentage of certain of the major alloying elements be increased or decreased in accordance with their observations on the behavior of steels of this type.

The amount of chromium added to the 9.00 to

11.00% tungsten steels is between 1.75% and 3.50%. One steel manufacturer claims that the presence of over 2.00% chromium in high tungsten steels increases their tendency to heat check and is therefore undesirable. On the other hand, however, a great many steel companies make claims for high tungsten steels containing greater than 2.00% chromium.

A typical 2.00% chromium, 0.50% vanadium, 9.25% tungsten die steel has a maximum safe working temperature of 1200 F, a coefficient of linear expansion of 7.2×10^{-6} at 1000 F, and is used after being hardened to between 40 and 45 Rockwell C.

Three typical 3.00 to 3.50% chromium, 9.00 to 10.00% tungsten die steels are: (1) 3.50% chromium, 1.00% vanadium, 9.00 to 10.00% tungsten, (2) 3.50% chromium, 0.45% vanadium, 9.75% tungsten, and (3) 3.10% chromium, 0.45% vanadium, 9.50% tungsten. These are widely used today with good results up to 50,000 shots.

The first of these, which contains 1.00% vanadium, possesses a high red hardness and freedom from heat checking. The carbon content of this type of steel is very carefully controlled as it has been demonstrated that there is a definite relation between heat checking and the higher carbon ranges. The carbon content of this steel is kept within the range 0.30 to 0.35% to assure its ability to be heat treated to a hardness of 444 Brinell and at the same time to assure it freedom from heat checking. This steel possesses excellent properties at elevated temperatures.

The second of these die steels is heat treated to between 40 and 45 Rockwell C prior to use. It possesses a coefficient of linear expansion of 7.23×10^{-6} at 1100 F, a tensile strength at 1000 F of 160,000 p.s.i., and an ultimate tensile strength of 215,000 p.s.i. at the same temperature. Its maximum safe working temperature is 1200 F.

The third is also heat treated to a Rockwell C of between 40 and 45; however, its maximum working temperature is 1400 F.

Still another die steel of the same type, *i.e.*, a low carbon, hot work steel, which has medium strength at elevated temperatures and excellent red hardness, is generally tempered to a hardness of 444 Brinell, manifests a red hardness of 125 at 1500 F, and a hardness of 105 at 1600 F.

One steel concern adds between 1.50% and 1.75% molybdenum to a 2.75% chromium, 9.50% tungsten steel, claiming that the addition materially improves the hot properties of this type of steel. Another adds 1.50 to 1.75% nickel to a 2.50 to 3.00% chromium, 9.00 to 10.00% tungsten steel—a similar claim.

Four tungsten die steels are offered that contain between 14.00 and 15.00% tungsten. The chromium content of these is different in each of the four types. One contains 2.75% chromium, another 3.00%, another 3.50%, and the last 4.00%. Many die casters claim that these 14.00 to 15.00% tungsten steels do not stand up as well in service as the 9.00 to 10.00% tungsten steels.

Recently a new type of die steel has made its appearance. This die steel has as yet not been proved superior to either the 9.00 to 10.00% tungsten steels or the 14.00 to 15.00% tungsten steels, but it is hoped that it will do so. This type of 1:1 chromium-tungsten alloy steel has made its appearance in two distinct alloy types. One has 7.50% chromium equal tungsten, and the other has 12% each of chromium and tungsten. The performance of both of these die steels bears considerable watching. Each contain in addition to the chromium and tungsten approximately 1.00% vanadium as an alloying element. The 12:12 chromium-tungsten alloy steel has a maximum safe working temperature of 1550 F and is used with a hardness of 32 to 44 Rockwell C.

Conclusion

Most of the contemporary steels offered by various steel companies are known to be suitable for certain die casting die applications and are sold with this understanding. At present no steel with indefinite "life" possibilities is offered for even zinc base alloys. Certain die casters have, however, successfully made over a million zinc alloy die castings from a single cavity die and completed the fabulous order before "heat checking" became so pronounced they had to stop making the die castings.

Because of the fact that those steels which are capable of lasting the longest under the most severe service conditions are considerably more expensive than the less resistant die steels, steel manufacturers point out that for certain applications less expensive steels should be considered for the job.

It is known that certain steels are better able to withstand the deteriorating effect of continued use than other steels. Those steels which are able to render long service life are more costly. Therefore, it is always necessary to determine before purchasing the die steel whether the quantity of die castings demanded by the customer warrants using an expensive steel. Naturally, it is always advisable to avoid purchasing a better grade than the occasion demands.

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MATERIALS & METHODS MANUAL

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This is another in a series of Manuals on engineering materials and processing methods, published at periodic intervals as special sections in Materials & Methods. Each of them is intended to be a compressed handbook on its particular subject and to be packed with useful reference data on the characteristics of certain materials or metal forms or with essential principles, best procedures and operating data for performing specific metalworking processes.

Induction Heating

by Edwin Laird Cady

This manual discusses the subject of induction heating from the economics standpoint, since that phase is probably the least understood. That induction heating is satisfactory for a wide variety of applications has been proved, but when this method should be chosen over competitive methods is not always recognized. Mr. Cady points out where, why and how induction heating applies. Numerous examples illustrate both typical and unusual applications of induction heating for hardening, brazing, soldering and other types of tasks.

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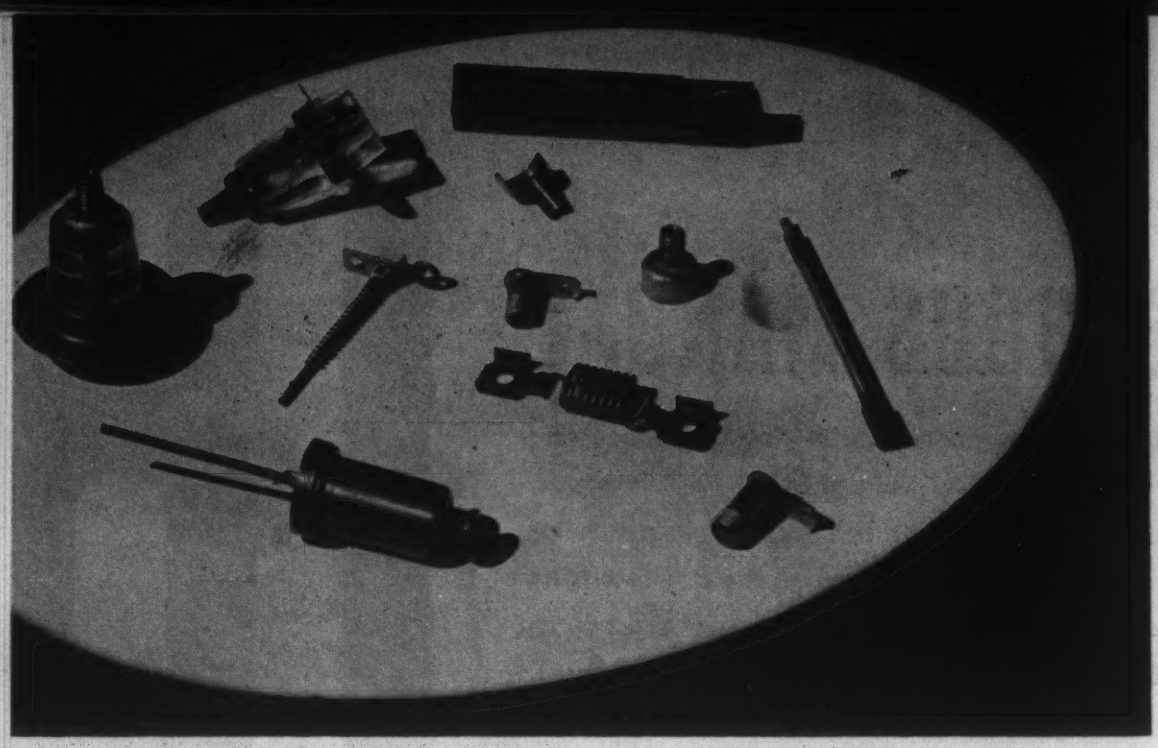


A typical group of parts now being inductively brazed by a 5-kw. electronic heater. (Courtesy: General Electric Co.)

Introduction

This manual covers some of the applications of induction heating to the fabrication of metals. It does not cover all of them; probably no one man or group of men knows what all of them are. It excludes ordinary operations of metals melting as these present problems quite different from those involved in heating.

Within that scope induction heating could be described as a method for obtaining closely controlled amounts of heat (BTUs), within definite and preselected areas of the work piece being heated, to heat those areas to exactly controlled temperatures. In short, a way of getting the temperatures wanted in the work piece, in the areas where they are wanted, without getting them anywhere else.

The word "area" must be construed to include the depth below the surface to which the controlled temperature penetrates as well as the dimensions of the surface area heated. And to all that must be added the factor of speed of heating; the speed with which the desired temperature is obtained being highly controllable.

Induction heating thus becomes: controlled temperatures obtained at controlled speeds within controlled areas.

The work piece is heated electrically by alternating current but without coming into physical contact with the power source. The piece acts as the secondary in a transformer. As defined by the National Electrical Manufacturers Association, induction heating is "the heating of a nominally conducting material due to its own I^2R losses when the material is placed in an electromagnetic field."

The electromagnetic field is set up within and about a work coil or inductor.

The *speed* with which the work piece area is heated depends upon the amount of power or energy forced into it via the electromagnetic field and upon its own response to that power, various materials responding to varying extents.

The *amount* of power forced into a given work piece area depends first upon the amount supplied to the electromagnetic field and second upon the closeness or the proximity of "coupling" of the work piece area to the inductor.

The *depth* to which the desired temperature penetrates depends initially upon the cycles per second of alternating current—the fewer the cycles the greater this initial depth—and second upon the time during which the heat units supplied to this initial depth are permitted to be transferred by conduction to greater depths. And since the time duration of heat conduction usually is determined by the speed of heating, the depth of penetration is dependent as much upon speed of heating as upon cycles per second.

The *surface area* heated depends upon the dimensions of the electromagnetic field intercepted by the piece and having enough energy to heat the piece, and upon the length of time in which the heating is done and conduction can take place. In addition, surface area heated can depend upon cycles per second of the current, but in a way which is exactly opposite to the effects upon depth. The more the cycles per second the greater the tendency of the current to follow the surface contours of the piece and therefore the greater the control of the surface areas to be heated, but the less the initial depth of heat penetration.

Of course, all of these factors vary widely in their applicabilities to different materials, work pieces and sizes of production runs. That is why there are so many different sizes and kinds of induction heating equipment for sale. These factors have to be combined and controlled so closely that most induction heating equipment is so carefully designed and made that it must be classed as a machine tool. And in these induction heating machine tools:

The amount of power fed to the heating coil or inductor must be adequate for the work to be done, and must be controlled with sufficient closeness for the work.

The inductor must be of such size and shape as to create the desired heating pattern on the surface of the work and to permit the necessary closeness of coupling.

The work piece must be positioned, usually by mechanical holding devices, with such accuracy that the closeness of the coupling will be adequately controlled while the desired area of the piece is exposed to the electromagnetic field. In addition, the piece may need to be revolved, moved axially or otherwise be moved in relation to the inductor, or the inductor can be similarly moved in relation to the piece.

The cycles per second must be controlled to the need for following surface contours of the piece and also establishing the depth of initial heating. In some machines these cycles are at fixed rates and everything else must be adapted to them; in other machines they can vary over wide ranges.

The time period during which the work piece is exposed to the electromagnetic field must be controlled in order to control the depth, the surface area, and sometimes the temperature of the heating. This usually calls for automatic timing devices.

The work handling devices must be adequate, not only for controlling the positioning and the timing of the work, but also for keeping the "floor to floor" time of each successive work piece low enough so production will be high enough and costs low enough to pay profits.

The entire operation of the machine must be kept in such electrical balance as is needed by the machine itself. This factor varies widely with different machines and with different applications of the same machines. Like the matter of never so powering and loading a lathe or other machine tool that the power demanded for the work is out of balance with the power available at the motor, this electrical balance factor never should be overlooked.

Induction heating equipment is available with power output ranging from a fraction of a watt to those of more than 1000 kw., in physical dimensions and weights ranging from machines which could be operated on top of a desk to those which would fill a large room, with cycles ranging from the 60 or other nominal number per second found on ordinary power lines to the 50,000,000 cycle jobs used for hardening thin section pieces which have tricky contours.

Induction heating equipment is, then, a whole family of machine tools. They follow many of the economic and functional rules which apply to all machine tools.

They may cost as much as good machine tools or more and must be operated and maintained as carefully.

They can be as flexible and adaptable in application as simple engine lathes, and can suffer the penalties of misapplication and overloading which are common to adaptable machines. They can be specially

built "from the floor up" to work with highest economy on just one size and type of work piece, and can need to be completely torn down if they are to be converted to work on anything but a highly similar work piece. The basic machine cost including the inductor can be 99% of the whole cost of tooling up for a job, and in other cases the mechanical devices for materials handling and for work positioning and control can be so great that the basic machine cost can be less than 1% of the total equipment cost.

The number of cycles per second can be established by using those standard for power lines, by rotary devices, by spark gaps, by electronic circuits with tubes, by rectifiers, and perhaps by other means.

Basic Types of Equipment

Induction heating machines can be classified by the means by which their frequencies are established, and by the frequencies themselves. The means are:

1. Electronic circuit
2. Spark gap
3. Rotary converter
4. Mercury arc
5. Standard power cycle

Of these the spark gap and the electronic circuit are most important in the numbers of machines in use and the rotary converter, standard power cycle and mercury arc are the most important appliers of power in amounts over 30 kw. per machine.

Many of the most important builders of induction heating equipment will use any of these means which seem best fitted to the jobs to be done. Such houses are machine tool designers in the complete sense of the word. They may prefer some kinds of machines but they are not married to any.

Frequencies run from 50,000,000 down to 25 cycles per sec. Within wide limits there is no "sacred number of cycles." Many factors vary with the square roots of the number of cycles used, therefore the effects of variations in the numbers of cycles are much less than as if those factors varied directly.

One laboratory experimented with hardening a 2-in. dia. piece of steel to 0.020 in. depth. 100,000 cycle equipment was tested against 500,000 cycle. In theory the initial penetration of heat at 100,000 cycles would be 0.002 in. and at 500,000 cycles 0.001 in. But a definite amount of time had to be used in revolving the work within the inductor. Within this time no difference between the hardening speeds of the two types of equipment could be measured.

One factory is able to harden, with 20 kw. equipment at 2,000,000 cycles, pieces of 12-in. dia. at 1600 F, 10-in. dia. at 1800 F, 8-in. dia. at 2200 F. Another does not attempt to use its 20 kw. approximately 500,000 cycle equipment to harden any piece over 5-in. dia. The first of these two equipments costs nearly twice as much as the second.

When extreme power at high cycles is to be used the equipment maker usually specializes on such machines and their applications.

Any comparisons of types of machines, then, can have only very general meanings. There is no substitute for inquiring directly of equipment manufacturers.

Megacycle Types

Equipments working at over 1,000,000 cycles are electronic circuit jobs. They are to be had in power capacities from 300 w. up to 25 kw. output, with various capacities in intermediate ranges, and with capacities up to 75 kw. output planned. Their voltages are high, up to 5,000 v. This brings a flashover problem between the inductor and the work.

These machines are very good where thin work is to be hardened, where control of the area to be hardened must be extra close, where the heat must follow difficult contours. They compare to lower frequency machines somewhat as grinding machines compare to lathes. Their makers and users estimate that an extreme limit of 7% of all induction heating jobs are best handled by these frequencies.

Ordinary Cycle Electronic

More common electronic cycle machines range from 300,000 to about 530,000 cycles, with 450,000 cycles the most usual. The most popular models have about 20 kw. outputs, but these machines can be had with capacities ranging from a few hundred watts up to 200 kw. in standard sizes. Special machines with any capacities desired can be made by ganging several tubes.

Remembering that the work piece becomes the secondary in a transformer, as a general rule the work piece and the inductor have to be brought into electrical balance with the circuits of these machines, and this requires careful engineering generally followed by much "cut and try" to get each new job going. But with minor modifications these machines are capable of and are being used for an infinite variety of set-ups.

Spark Gap

Spark gap converter machines are highly flexible. They are easy to "tune" or to adjust electrically to the work piece and the inductor. To a large extent they adjust themselves, varying their frequencies and their power outputs to the needs of the work.

To some extent this flexibility is their best friend. They can be set up readily for wide varieties of jobs. Some shops are unable to use any other kinds of machines.

This flexibility also is the worst enemy of the spark gap machine. If equipped with a badly made or applied inductor a spark gap machine may struggle and produce the desired heat in the work piece, although the maintenance bills on the machine will be increased. The spark gap machines also can be run in detuned settings, without any real effort being made to use the dials with which they are equipped and bring them into correct settings. This practice also results in raised bills and troubles for maintenance.

Like many another flexible machine tool, then, the spark gap gains from intelligent management and loses by careless supervision.

The day to day inspection and maintenance cost of a spark gap machine usually is higher than that of its closest competitor, the electronic tube type. But the annual maintenance cost as compared to the costs of replacing tubes may actually be lower.

Because of their tuning feature, spark gaps are rated at ranges of cycles rather than in fixed cycles. The most common machines are of about 125,000 to 450,000 cycles range. Other types are of 15,000 to 60,000 cycles range.

Some models are completely self tuning.

In the course of balancing themselves electrically to their work, spark gap machines can work at efficiencies ranging from very low to over 66%. Because of this wide range within a single machine it is easier to rate them by their input capacities than by their outputs. Input capacities range from a few watts to over 40 kw.

Rotary Machines

Rotary machines are made with cycles ranging generally from 1,000 to 10,000, and output capacities ranging from 50 kw. up to 1500 kw. They dominate the field within these power ranges.

Their low cycles give them deep penetration which is good for heavy work, for through heating, and for forging. They are high in efficiency.

Most rotary machines are sold by companies which buy motors, converters, transformers, capacitors and other electrical equipment from the major electrical companies, then engineer the rest of the machines. These companies therefore can be highly adaptable in their selection of basic equipments for their machines, and can vary the machines to the needs of the work. Or with equal ease they can build many machines which are basically duplicates of each other but vary them in a few electrical details and in all the details of the work handling devices.

Mercury Arc

So far as is known, only one of the new mercury arc units has been used for heating. Several have been used for melting. Further progress of this type will be watched carefully.

This equipment can range from 400 to 3,000 cycles, with the most common range expected to be 1,000 to 2,000. It may be higher than the rotary machines in effi-

ciency. It has an ability similar to that of the spark gap machines, but over a narrower range, to adjust its own resonancy to the changing needs of the work.

So far as is now known this equipment seldom will be made in capacities of less than 300 kw. output. But at this moment the limits of its size and of its economical applications are totally unknown. It is the dark horse of the induction heating field.

Standard Power Line Cycle Equipment

Induction heating equipment using the 60 cycle currents supplied by many power lines, or the 25 cycle ones generated in some mills, or any other standard power line cycles, can be highly economical and very useful in forge shops, for heavy annealing, for hardening large parts and for many smaller operations.

Such equipment has not been publicized as much as the higher cycle ones, consequently it is less understood. Three misconceptions about it expressed by engineers who were interviewed in the preparation of this manual were: (1) standard power line cycle equipment can raise steel above the Curie temperature only at high cost and with great difficulty, (2) any ordinary electrician can design and make such an equipment if it is wanted, and (3) this equipment cannot heat anything below 4 in. in dia.

To deal with number (3) first, standard power line cycle equipment is used to anneal pipe of 1-in. dia. and less.

For work of 4-in. dia. and over, one user has 8 units averaging 350 kw. each, four being used on one job and the others on individual tasks. Each of them heats steel to 2300 F, which is far above the Curie range. Each required at least 6 months of highly complex electrical engineering and experiment to get into action.

The physical costs of such equipment is surprisingly low. These 8 cost about $7380 each or about $22.00 a kw. For the more common, higher cycle equipments, $100.00 a kw. is a low cost although $50.00 a kw. has been attained. But the engineering story is different. Design and experimental costs are high.

Setting up costs are high also. This user does not consider it worth while to work out one of these equipments unless it is going to average at least eight months of steady operation a year. With that much use it will repay all design, experiment, physical and setting up costs with a profit.

Another user has such an equipment in a forge shop. The story is much the same. The cost of the first equipment for a specific task is about three times that of a second one. When a new task has to be performed the cost for the first equipment is just as high and the experimental time just as long. One engineer said: "my clients think I am gypping them but it costs about $5,000 to design a 60 cycle inductor and $500 to build it."

In action, 60 cycle equipment commonly is used with couplings as loose as 1 in. in order to protect the inductor against the heat of the heavy sections which usually are heated, and the inductor can be protected further by a heavy asbestos shield.

The low cycle current penetrates the work piece so deeply that there is little of the "skin effect" common to higher cycle heating. In fact, radiation losses from the outside of the piece can be great enough so the interior is hotter than the periphery and forging is done at lower visible temperatures than would be used for furnace heating.

Although one user is reported to have 30,000 installed kw. of 60 cycle equipment of closely guarded secret design, many of the engineering and application principles of standard power line equipment have yet to be worked out.

There are many electrical problems such as obtaining high power factor, overcoming or counterbalancing magnetic thrust which in the heavy electromagnetic fields created at these cycles can force the parts to be heated out of the inductors, and building up high inductance by the use of laminated iron in the inductors.

Aside from these installations which require highly imaginative electrical engineering, there are hundreds of simpler ones which any well informed shop electrician can work out. These are used for expanding parts for shrink fits, heating autoclaves, and other purposes which do not require high rises in temperatures.

Economics of Induction Heating

With so many electrical and mechanical means available for induction heating equipments there has been a great temptation for anyone who discusses the subject to get lost amid the empiricisms and imponderables of electrical circuits, electronics, the exact amount of heat generated by hysterisis in a magnetic material work piece *vs.* the amount generated by eddy currents, the value of deep initial penetration of heat into the surface *vs.* the speed with which heat from a shallower initial penetration will progress by conduction to the desired depth, and so on.

Any engineer who has watched the development of any industrial "science"—die casting, for example—will see that in spite of the fact that nearly every induction heating equipment must be a completely organized machine tool, induction heating itself is only an art. It has not reached the industrial craft stage as yet, let alone that of an industrial science. And it is an art having more bewildering, amazing and contradictory possibilities than any other ever offered to industry.

The obvious path for engineers to follow has been the one commonly used in the development of all industrial arts. Prospective users of induction heating have picked out the fields of application in which the process is most likely to pay large and immediate profits. Equipment makers who know more of the answers than anyone else in regard to the electrical circuits, electronics and the like, have designed special or semi-special equipments for these applications. Since the user who has been successful with one application has been the one most likely to try induction heating on another, a high percentage of all induction heating equipments have been sold to just a few users and for applications of the highest profitability.

A second and broader highway of development has stemmed, as is common with industrial arts, from the first. Individual makers have standardized as much of the basic parts of their equipments as they could, and have built their specialized application equipments upon these standardized foundations. This has been much like the common machine tool custom of building a standard lathe or milling machine as a "chassis," and then putting on additional motors with different gearing and electrical controls to fit the machine for special tooling. But these semi-special induction heating machines have been built largely by men who are designers and assemblers rather than manufacturers. Motor generator sets have come from one manufacturer, electronic tubes from another, transformers and capacitors and timers are also bought outside. The temptation has been to modify everything which is not so self-integrated and expensive that its modification would be too costly, and to engineer these semi-special jobs inside and out for highest applicability to narrow ranges of work. Much equipment intended to be standard with special modifications has become spe-

Steel slugs 3⅜-in. dia. by 1¾-in. long are heated to forging temperature at the rate of 350 per hr. in this Ajax-Northrup induction heater. Power at 1000 cycles is provided by a 200-kw. motor generator unit.

cial with standard modifications.

Like the completely special ones, these partly standard machines have tended to congregate in the hands of users who already know how to profit by induction heating, and to be applied to tasks for which their profitabilities are safely predictable. And in line with a custom which almost has the force of a law in industrial management, the higher the profitability of a machine for a given task the greater the tendency to "specialize" that machine and its equipment so as to make it still more profitable for that task.

At least 25% of all induction heating equipment, then, and nearly 100% of the costlier types, have been specially engineered for narrow fields of application with any facilities for converting them to new tasks being secondary considerations only. Many a user knows so little about his equipment that he depends upon calling in the engineers of its maker whenever he wants to convert it to a new task, and more than one maker and seller believes that this re-engineering is the ideal way to handle induction heating equipment units in their present state of development.

This situation has tended to limit the uses of induction heating, the number of plants which have it, and the forces of engineers and of trained supervisors and maintenance men who understand it.

The extent of flexibility of the other 75% of the equipment in use is a matter of degree only. Some equipment has been made so flexible that it is practical for a single machine to be set up as many as 16 times to perform 16 different tasks in a single day. For some types of machines standard inductors of the hairpin variety have been so worked out that it is possible to perform many different tasks at a single setting. Nevertheless, even with the most flexible types of machines the tendency has been to create special and complex work handling and positioning devices, timing controls, etc., and so to limit each machine to narrow ranges of work.

The inherently flexible machines, like the less flexible ones, have tended to be applied to tasks of the most obvious profitability and to be bought largely by users who already have learned how to profit by induction heating.

There are definite signs that induction heating is moving into the third common phase of the development of an industrial art, that of widespread general adoption by users who did not care to experiment with the earlier development stages.

A general review of the present status, as found by interviewing users and makers of the equipment, shows this picture:

First Cost

In view of the fact that induction heating equipment is comprised of a whole family of machine tools, first costs can run anywhere from less than $500 to over $500,000 for an installation. Proposed for Russia: A $3,000,000 installation. One firm of consulting engineers which has installed and recommended a great many of all kinds of heating equipment finds that induction heating equipment costs from two to twenty times as much as oil or gas fired equipment to do the same general classes of work. The induction heating equipment has to justify this by its advantages.

This 200-kw. induction heater heats the end of a steel tube to a temperature of 2350 F for a length of 18 in. prior to upsetting. For this application the heater is mounted on track. (Courtesy: Tocco Div., The Ohio Crankshaft Co.)

In an astonishing number of cases the induction heating equipment costs seemed to be just about in line with that of the other machine tools in the production line. That is, if $10,000 worth of automatic lathes or of punch presses and dies were needed to fabricate a given part then about $10,000 worth of induction heating equipment would be needed to handle the output, which might then go on to whatever final grinding and finishing equipment happened to be necessary. There is no logical reason why these figures should be closely in line on a dollar for dollar basis. The impression gained by observation is that induction heating equipment costs are just about in line with other machine tool costs for the same volume and quantity of metal parts flowing down the production line.

Amortization, Depreciation, Obsolescence

Practically every induction heating machine made is still at work, or still is in condition to work.

Some of them date back fifteen years. This means that it is safe to depreciate the machines themselves, in most cases, over a period of at least ten years.

There are some high voltage types with frequencies to the order of 2,000,000 cycles which, according to their makers, might better be depreciated over five years. But the makers do not cite any cases nor any indications of the machines wearing out within that time.

For the most part induction heating machines do not have any bearings or moving parts subject to heavy continuous loads nor to shock loads. There are no beds to be sprung out of alignment, no ways to wear, few corrosion problems which cannot be solved by ordinary careful protective maintenance. Parts subject to common electrical or mechanical damage are easily replacable. Operating conditions which would suggest rapid depreciation of whole machines are rare.

Some special machines, particularly of the 60 cycle and other standard power line varieties, are made for single operations and obsolescence must be planned for whenever those operations are discontinued. Usually, plans can be made for salvaging important parts of obsoleted machines.

Improvements in standard models of machines take place continually. But the older machines commonly are so profitable for the tasks to which they are applied that there is no reason to obsolete them as no longer being economical.

There can be obsolescence of parts of machines. For example, the conversion of a machine to a new task may require different transformers and capacitors with the old ones being obsoleted. Inductors also may be obsoleted at the time of changeover. But such changes rarely cost more than a fraction of the price of a new machine. They are to be regarded as obsolescence of tools rather than of machines.

Work positioning devices, controls, materials handling equipment, quench tanks and the like are a different story.

These are to be depreciated, obsoleted and amortized just like any other equipment of their kind serving other machine tools in the plant. Some of them are subject to heat damage. They may undergo shock loads, vibratory loads, corrosion and other damage in accordance with their tasks and the skill with which they are designed and made. Where likelihood of damage is great depreciation must be rapid.

These devices also are subject to obsolescence, in most cases, at the ends of the production tasks for which they were made. Sometimes they can be slightly redesigned and converted to other tasks. Most of them have speed changers, motors and other parts which can be salvaged.

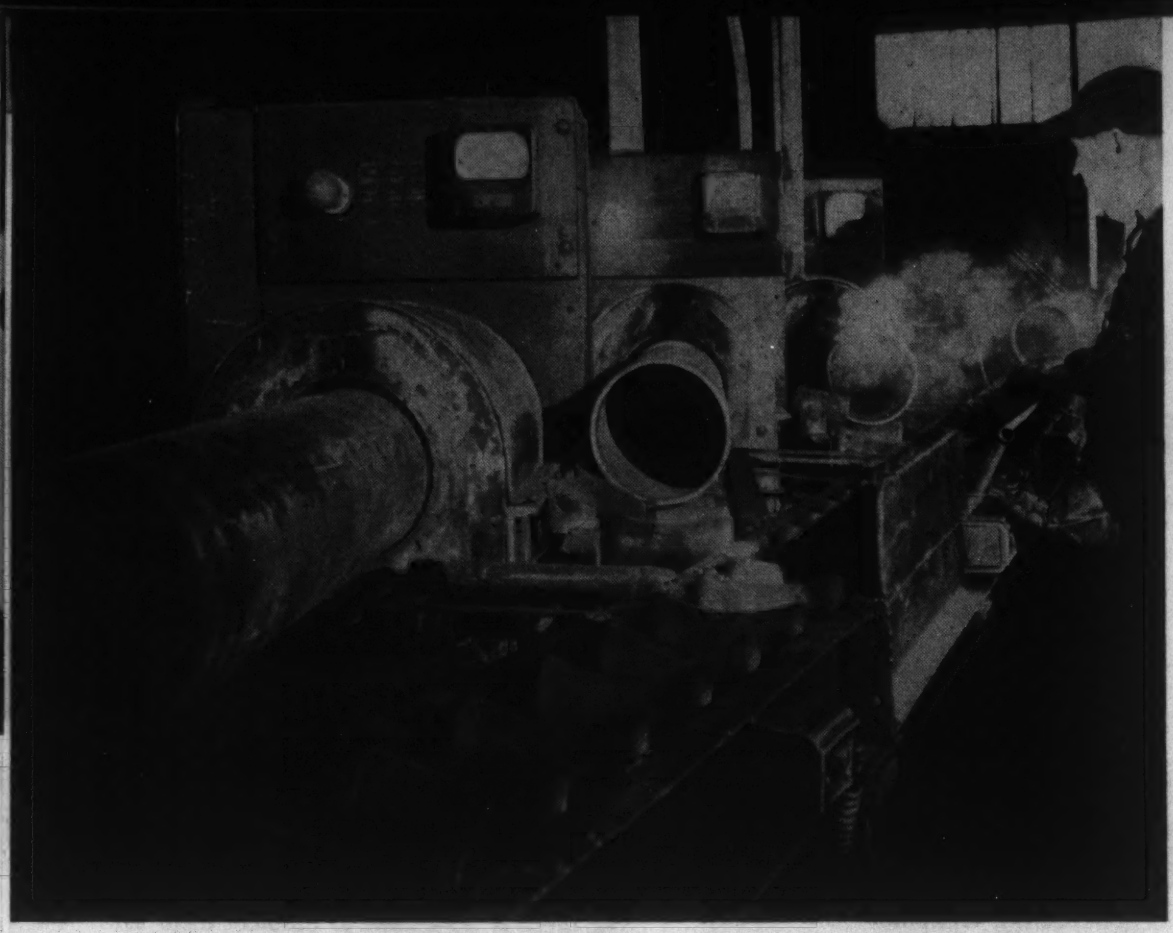
The induction heating machine, then, should be depreciated over a period of at least ten years unless there is something unusual about it that requires its depreciation or obsolescence in a shorter time. The work handling equipment that works with it should be depreciated or obsoleted in a much shorter time.

Relation of Machine to Equipment Costs

The relation of the costs of induction heating machines to those of the work handling equipments can vary as widely as those of any machine tools to their toolings.

One $85,000 complete equipment for hardening 48-in. dia. gears includes about $70,000 for electrical equipment including a hydrogen cooled generator, and $15,000 for work handling equipment. The machine is 700 kw. capacity.

Another 20 kw. output machine was specially set up to harden the prongs of shifting forks, the forks having been made of 1020 steel which was carburized,



With the advent of hot spinning, induction heating found another application. Here is one such set-up. (Courtesy: Ajax Electrothermic Corp.)

allowed to cool in the pots, then induction hardened so only the prong ends would be hard. The combined cost of the special inductor and of the work handling equipment including conveyor belt and motor was $300. This cost is to be completely amortized and the equipment broken down at the end of the production run.

Again, joining of alternate glass and Kovar rings to make 2,000,000-v. X-ray tubes at Machlett Laboratories includes jigging the alternate rings on a special expanding mandrel and rotating this mandrel at 60 r.p.m. while it travels past interior and exterior inductors. The cost of the spark gap machine which supplies the power and governs the frequency for the induction heating was about $3800. The cost of the work handling equipment including special development and experimental expense is well over $20,000.

One maker of 20 kw. output machines which sell for slightly over $5,000 reviewed his sales for the past several months, found that the lowest cost for special work handling equipment supplied with each new machine was $200 and the highest was $3500 but the most typical was in the range between $1500 and $1800.

The values of more expensive work handling equipment for these machines are the same as those for any machine tools. Sometimes the equipment is needed to permit the machines to perform the tasks at all. More often the equipment permits the machine to produce more nearly to the limit of its capacity, spreads the cost of the machine and its equipment over more work pieces and so reduces the cost per piece, cuts down on the floor space needed for a given amount of production, eliminates the need to buy an additional machine to take care of increased output, promotes quality control, and the like.

Relation of Efficiency to Other Costs

The efficiency of an induction heating machine is the ratio of the power available at a good inductor to the power input to the machine. This efficiency ranges generally from 50% to nearly 90% depending upon the type of machine. There is considerable argument as to just how high that efficiency is for various machines.

The heating efficiency of the complete equipment depends first upon that of the machine and second upon that of the input to the work piece. With a close coupling (close proximity of the surface of the work piece to that of the inductor) this efficiency is high. With a loose coupling it is lower.

In one large forge shop the power cost for induction heating is over $150 per operating hr. Here it is worth while to spend extra money to secure higher efficiency.

Another forge shop has 3600 kw. for forging, 1300 kw. for hardening and 45 kw. for brazing. All the forging kw. is operated at about 3,000 cycles. By varying the cycles for some of the jobs it would be possible to increase the efficiency. But it is considered more economical to keep all cycles uniform so as to have one less variable to deal with when changing an equipment from one forging job to another.

The tighter the coupling the higher the cost of work handling and especially of work positioning equipment, in most cases. Often it is economical to sacrifice efficiency to reduce equipment costs. One machine on which tasks are changed quite often will operate at 75% efficiency with a tight coupling and only 10% with a fairly loose one. It has been operated at only 1.5% on a task where only one piece was hardened every 5 min., the hardening time and therefore the duration of power consumption was only 6 sec., and the production of that work piece occupied the machine for only one day a month.

One machine which delivers about 40 kw. has a recorded average power cost of $1.60 an hour. Efficiency never deliberately is sacrificed to carelessness, but nevertheless is considered less important than convenience of set up.

A tube manufacturing company uses gas heating for all carbon steel tubes and induction heating for all stainless steel. Because of the type of gas heating equipment and some of the operating problems the gas furnace runs at about 8% thermal efficiency and the induction heating at 80%. At these figures the cost for fuel is just about equal to the cost of electricity per BTU delivered to the work.

A shop which routes hundreds of different parts for hardening and of assemblies for soldering and brazing to three induction heating equipments one of which is 20 kw., a second 40 kw. and the third 100 kw., breaks its induction heating costs down into ten dollar units for comparison purposes. Of each $10.00 of operating cost including labor, materials, supervision and direct overhead but not general administration or "front office" burdens, power averages $0.45 or less than 5%. Power is by far the smallest item in the $10.00 unit. The largest item is the cost of setting up the machines and experimenting with inductors for new jobs.

A dollar saved on the power bill looks as big as any other dollar on the annual profit and loss statement. But with the exception of equipments which are coordinated to steady operations on single parts or tasks and upon which power efficiency is easy to study, most users appear to think mostly about operating effectiveness and very little about power efficiency.

This neglect of thinking about efficiency can lead to serious overloading of some types of machines. In some cases this means no more than that protective devices will have to be reset. In other cases, especially on brazing and soldering jobs, the work is spoiled when the protective devices cut off the power in mid operation. The worst penalties are in shortened lives of electronic tubes and in increased maintenance costs for spark gaps.

General Advantages

Induction heating is not always the most economical or effective method. But where it works out it usually is highly advantageous.

Overall costs of heating are reduced. When previous methods required subsequent straightening, scale removing and other corrective operations the savings by induction heating have been over $5.00 per piece heated. In other cases the savings per piece have been fractions of a cent but on long production runs they have been well worth while.

Heating is made more of a production line operation. An induction heating equip-

ment which is to heat treat the output of an automatic screw machine, for example, can be put directly in line with the screw machine and rigged to take the parts exactly as fast as the screw machine delivers them. If the screw machine delivers one part a second then the induction heating equipment can be selected and set up to heat treat one part a second, resulting in a continuous and straight line flow of parts to the next operation. Similarly, an induction heating set-up can take the production of a battery of punch presses and solder the stamped parts together at the exact rate at which the battery delivers them.

Production is further straightened by exact control of distortion, of scale, and by general elimination of heat treating variables. The more these variables are reduced the greater can be the amount of work done by the less costly primary operations such as machining and the less need be the work done by higher cost secondary operations such as grinding.

Induction heating is one of the best resources of the stress engineer. By exact control of the areas hardened it can enable him to stiffen some areas, toughen others, and thus cause the stresses to gather at the points where they will do the least damage. Example: A gear is being hardened at the wear areas of the teeth, and toughened only at the roots, but the stresses concentrate at the specially contoured root areas. The gear therefore is being made 20% smaller than was necessary when all areas of it were hardened uniformly.

The stress engineer also is able to control the amounts and directions of his residual or "locked up" stresses. Example: a tube is simultaneously heat treated on the bore and on the periphery; the stresses oppose each other and when the tube is cut open for fabrication there is no significant amount of springing or distortion. Age distortion or "warp and creep" can similarly be controlled.

Sequences of operations can be changed to promote accuracy and eliminate operations. Example: A cam formerly was machined including boring, hardened throughout, ground in the bore, ground on the periphery. Now it is machined with the exception of boring, induction hardened on the periphery, chucked by the periphery and the bore is drilled and reamed. The cam thus has satisfactory accuracy with two grinding operations eliminated.

Metallurgists take advantage of the process to use less costly carbon steels where alloy steels were required, or devote the savings to paying the increased costs for alloy steels where these are wanted, or combine two materials by welding and then only heat treat one of them in the finished part, or use surface hardened cast gray or malleable iron where they formerly used steel, and the like.

Extent of Use

The advantages of the process have tended to increase its use in shops that know how to use it; its new operating methods and the controversies about its electrical mysteries have tended to keep it out of many other shops.

This situation is correcting itself rapidly. But to date, as far as the figures can be ascertained, fewer than 6000 installations have been made, and fewer than 2000 factories have them.

Figures generally agreed upon by consulting engineers who specialize on this process, by equipment makers and by holders of patents indicate:

1. About 1300 machines of from 1000 to 10,000 cycles and ranging generally from 50 to 400 kw. output capacities are in use in not more than 300 factories.

2. Some 4500 machines of from 20,000 to 2,000,000 cycles but with 20,000 to 450,000 cycles the most popular range and about 20 kw. output the most popular size, are in use in not more than 1500 factories and with considerable overlap with the factories having the higher capacity jobs.

3. An unknown number of 60 and other standard power line cycle jobs.

Hardening by Induction Heating

Heat treating of steels seems to be the most common use of induction heating. It probably does not use the highest percentage of induction heating kw.; either forging or some of the steel mill operations (e.g., melting) would be tops in that. But the greatest number of installations seem to be used for hardening purposes.

Figures on several hundred different hardening tasks were obtained from shop engineers. These figures are not a survey. No attempt was made to be sure that adequate samples for statistical completeness were secured. No attempt was made to be sure that all figures were calculated on the same cost accounting bases or that all sources used all the factors such as effects upon secondary and primary operations in arriving at the savings made.

The figures represent the actual experiences of shop men and of consulting engineers who specialize on metal treating. Figures given by makers of equipment appear elsewhere in this manual but not in this analysis.

Percentage of Hardening Operations Best Done by Induction Heating

The International Electronics Laboratories is making a study to find the most economical heat treating methods for some 120,000 parts. So far, less than 25% have been found to "belong" to induction heating.

Two different specialized laboratories have found that even when parts supposed to be clearly in the field of induction heat treating are brought to them for study, from 20% to 30% of those parts had to be assigned to other heat treating methods as being more economical.

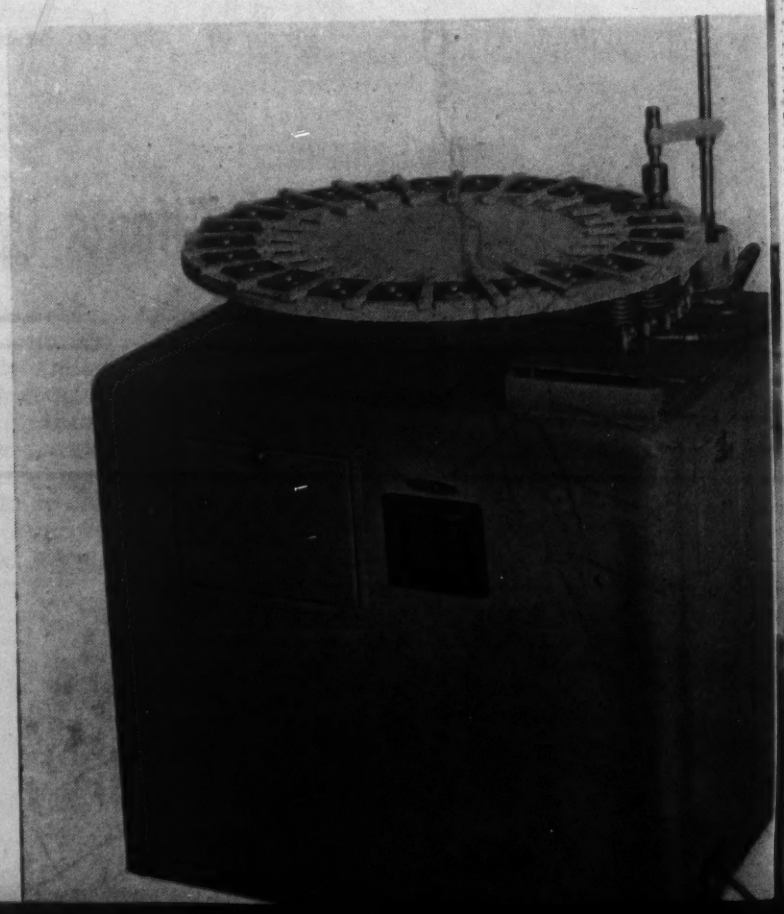
Engineers who use the process find that from 20% to 40% of their heat treating operations are best done by induction heating.

The equipment makers are conservative about this. One of the best things in this industry is the care with which equipment makers study products before recommending their equipments for processing them. Users of the equipment apply it to far more operations than its sellers had recommended.

Altogether, about one-third of all heat treating operations appear to be in the induction heating field.

The figures given here are the savings reported to be made by the use of induction heating. They are on a "per part treated" basis and do not include total number of any one part treated. Thus, a saving of only one cent per part might seem small as presented in these figures, but if applied to 10,000 duplicate parts it would be a larger net gain than a saving of $1.00 each on 50 parts.

The figures are divided into 10 cent ranges such as 0 to 10 cents saved on each piece treated, 11 to 20 cents, 21 to 30 cents,



Much of the value of induction heating comes through the development of special work holding and positioning devices. This is a 24-head automatic brazing unit. (Courtesy: Scientific Electric Div., "S" Corrugated Quenched Gap Co.)

etc. All savings of over $1.00 per piece are lumped.

Percent of pieces treated	Range of savings in cents per piece
26	0 to 10
18	11 to 20
16	21 to 30
15	31 to 40
9	41 to 50
6	51 to 60
3.5	61 to $1.00
6.5	$1.00 to over $5.00

Of the savings of $1.00 to over $5.00 per piece, 60% were obtained when hardening shafts. The highest savings were on hollow spindles which had to be hardened on bore and on periphery, with bearings surfaces or with gear teeth or other difficult contours on the peripheries.

Other high savings were found on gears, on worms where the threads only were hardened, on pistons with shoulders to be hardened, and on miscellaneous other parts.

Hardening of Ends of Pieces

The simplest production operation for which induction heating equipments can be set up is that of heat treating the ends of pins, shafts, forks, and similar pieces, the ends or faces of gear hubs when those faces are to act as thrust bearings; in short, to harden one or more ends of almost any piece. Such pieces can be caused to pass through the electromagnetic field of a simple hairpin shaped inductor. They can be mounted on conveyor belts or can be rolled by gravity so that one follows another and all travel at the correct rate of speed. The work handling device can be fed by a hopper so that the labor cost is very low. The heated parts can drop automatically into quench tanks.

Naturally, this simplest operation is the one most often used. Quite often the savings come from the fact that by previous methods the entire part had to be hardened to get the end hard, then there had to be corrective operations to remove scale or to straighten the part or to soften areas which had to be machined.

Percent of pieces treated	Range of savings in cents per piece
59	0 to 10
15	11 to 20
10	21 to 30
10	31 to 40

In 59% of these cases *vs.* 26% for the process as a whole, the savings were less than 10 cents per part hardened. In fact, in 34% of these cases the savings were less than 5 cents per part. But it is probable that the highest total of savings as measured by the number of parts hardened at one set up of an average equipment is secured when only the end of a part is to be hardened. The savings per part are not so large, but the number of parts of one size and kind probably is very large.

End hardening includes more than one-third of all the parts studied.

Teeth Hardening

The hardening of the teeth of gears, sprockets, clutches and the like seems to be the second most popular operation. The work handling equipment for this is likely to include exact timing mechanisms and means for rotating the parts while they are being heated.

Percent of pieces treated	Range of savings in cents per piece
30	21 to 30
20	31 to 40
15	11 to 20
14	41 to 50
11	51 to 60

The savings on this operation are much higher than the averages for the whole process. Here 30% are in the 21 to 30 cent range *vs.* 16% for the process as a whole, 11% in the 51 to 60 cent range *vs.* 6% for the process as a whole. More than twice as many are found in the ranges above 60 cents as in the range below 10 cents.

Teeth hardening applications make up more than half of all the uses of induction heating in many shops. They comprise nearly one-third of all the applications used in this study. This seems to be the use which is most rapidly increasing.

Many other uses were found, but in numbers too small to warrant complete break down. A few figures can be given on some of them.

Other Applications

On more than one-third of worm thread hardening operations the savings per piece were over $1.00. On another third these savings were less than 10 cents. The plain deduction is that some of the worms had to be made with extreme care and others could be treated as simply as end hardening operations. But the total figures were not large enough to be highly significant.

In 60% of cases the savings when bearings surfaces only were to be hardened were in the 21 to 40 cent ranges. It made some difference whether only one such surface was involved or if there were two or more of them.

When two bearings surfaces were hardened the savings were about one-third greater than for only one. When three were hardened on one shaft or other piece the savings always were over $1.00 per piece, but only a handful of such cases were found.

Savings per piece were spread fairly evenly from less than 10 cents to over $1.00 on shoulders. Some pieces had only one shoulder to be hardened, others as many as six. The number of shoulders seemed to make less difference than their positions, their contours, and the care with which the pieces had to be made.

Of the savings on internal hardening operations, 60% were in the 31 to 60 cents per piece ranges. This probably is to be interpreted in the light of the fact that hole hardening is one of the most individualized operations for which induction heating is used and seldom can any two such operations be directly compared.

Savings in the 11 to 50 cents per piece ranges tend to be spread evenly over these ranges in 80% of the cases. Cam hardening, like hole hardening, is highly individualized.

In 67% of the cases studied the Rockwell C hardness was increased. Many of these raises were accompanied by spreads in the limits, that is, the lower acceptable Rc would be raised by 1 point or so and the top by 3 or 4.

In 4% of cases the Rc was unchanged.

In 24% the top limit Rc was unchanged but the bottom limit was lowered by 2 or 3 points so as to spread the range.

Only 3% of the pieces studied had the Rc reduced. Another 2% were pieces which had not previously been hardened at all.

There is, then, no tendency to reduce the Rc when changing from another hardening method to induction heating. But in so far as these figures can give the picture, there is a tendency to spread the acceptable hardness range. Engineers said that this is not because the process lacks ability to control the hardening, but is because the process hardens so uniformly and so controllably that the former tightness of limits no longer was necessary for adequate stress engineering.

Effects Upon Kinds of Steel Used

Induction hardening often can permit lower priced carbon steels to displace alloy steels, or lower alloy steels to displace higher alloy ones. The savings are in the first costs of the steels and in costs to machine and to perform other operations.

The savings from induction hardening also can be used for reducing the costs of changing from carbon to alloy steels or from lower alloy to higher. And so far as the figures in this study can give the true picture, the tendency is to retain the high alloy steel already in use or to change from carbon to alloy when induction heating is used.

It could safely be predicted that the first applications of induction heating would be to parts which must endure heavy enough stresses so they would be made of alloy steels. And in 43% of all the cases studied the parts had been made of alloy steels when hardened by other methods and these same alloys were continued for induction hardening.

In more than 80% of cases *vs.* 67% for the field as a whole the Rc was increased when induction heating was adopted. Most of the cases also had the Rc limits spread.

In 10% of cases *vs.* 24% for the field as a whole the top Rc limit was retained but

the limits were spread by lowering the bottom one.

The savings in hardening costs per piece ran mostly below the 40 cent range but generally were higher than the averages for the process.

In more than 50% of the teeth hardening cases, the original alloy steel was retained when converting to this process, and almost always with an increase in the Rc. No other type of part showed such a high average of originally having been alloy steel. End hardening came second with 34%.

Alloy Steel Displacing Carbon

In nearly 27% of cases the conversion to induction heating was accompanied by a changeover from carbon to alloy steel. Thus some 70% of the cases studied were of parts made from alloy steel, 43% having originally been alloy.

When changing from carbon to alloy the tendency was to keep the top limit Rc as it had been for the carbon but to reduce the bottom limit, 70% of cases having been handled this way *vs.* about 26% in which the Rc was raised.

The reasons given for changing from carbon to alloy generally were that the part needed the extra strength and that the change would have been made even if there were no change in the heat treating method. But in a small number of cases the part either had to have the extra inherent toughness of alloy steel or else the changeover to the more controlled heat treating of induction heating could not have been made.

Often this changeover was accompanied by changes in the sequence of manufacturing steps so the hardening was performed on some areas and these were used as control surfaces for the machining of others. This resulted in higher accuracies of parts.

Savings on heat treating costs ran generally in the 21 to 40 cents per piece range and were higher than the average of the process as a whole.

About 25% of the teeth only hardening jobs were changed from carbon to alloy steel. With the 50% which originally had been alloy steel, a total of more than 75% of the cases studied of induction hardening of toothed sections were of alloy steel parts.

About 25% of the end hardening tasks also were changed from carbon to alloy steel, making a total of nearly 60% of these jobs which were alloy steel.

More than 50% of the bearings hardening jobs studied, more than 60% of the worms hardening, about 75% of the ones in which the holes only were hardened, were changed from carbon to alloy steel.

In about 20% of all the cases studied a steel of higher carbon displaced one of lower carbon in order to get enough carbon for hardening by this process. Example: 1040 steel displacing 1020. In another 5% the carbon already was high enough. In still another 5% of cases carbon steel displaced alloy, making a total of about 30% in which carbon steel was used.

In some 84% of these cases the Rc was increased, and in 8% it was unchanged from previous practices, making a total of 92% in which the Rc was equal to or better than that held by other hardening processes.

In 8% of cases the Rc was reduced. This is high compared to the 3% for the process as a whole, but it does not apply to very many cases.

A chain conveyor carries pieces to be soldered through the work coil. A dog on the side of the conveyor turns the fixture as it reaches wide part of the coil, to heat sides evenly. (Courtesy: Federal Electric Co.)

Savings per piece treated ran over 40% in the 0 to 10 cent range and also heavily in the 11 to 20 cent range and accounted for a high percentage of all the lower savings figures.

The cases in which carbon steel simply was retained when converting to induction hardening were found mostly among the end hardening jobs. Some 36% of all these cases were of this kind.

Those most interesting cases, those in which carbon steels displaced alloy steels, were found largely among the teeth only tasks. In more than 10% of these tasks carbon steels displaced alloy.

Predicting the Future

The figures in this study show conditions during a period when induction heating was just breaking away from the development stage of having only limited use by a few users. The period was complicated by the materials shortages and the haste for production of the war and the immediate postwar times. Users seem to have applied this method mostly to problems that nothing else could solve. In fact, more than one seller of induction heating equipment has reported himself as saying to some prospective customers "if you can do the job any other way then don't use induction heating."

Induction heating is leaving this development period, becoming far more widespread and common in use. As it does so it will be regarded less as a method solely for those parts requiring the ultimate in stress control engineering and in controlled area heat treating and in alloy steels, and more as a machine tool for outright production and parts design economy.

As this present development grows the savings per part heat treated will decline, the overall savings will increase with increasing sizes of production lots treated, the trend to displace lower cost steels with higher cost ones will continue in many applications but reverse itself in many others, the tendency to take advantage of this process to decrease machining and other fabrication costs will vastly increase. A study made five years from now would show quite different figures if compared to this one.

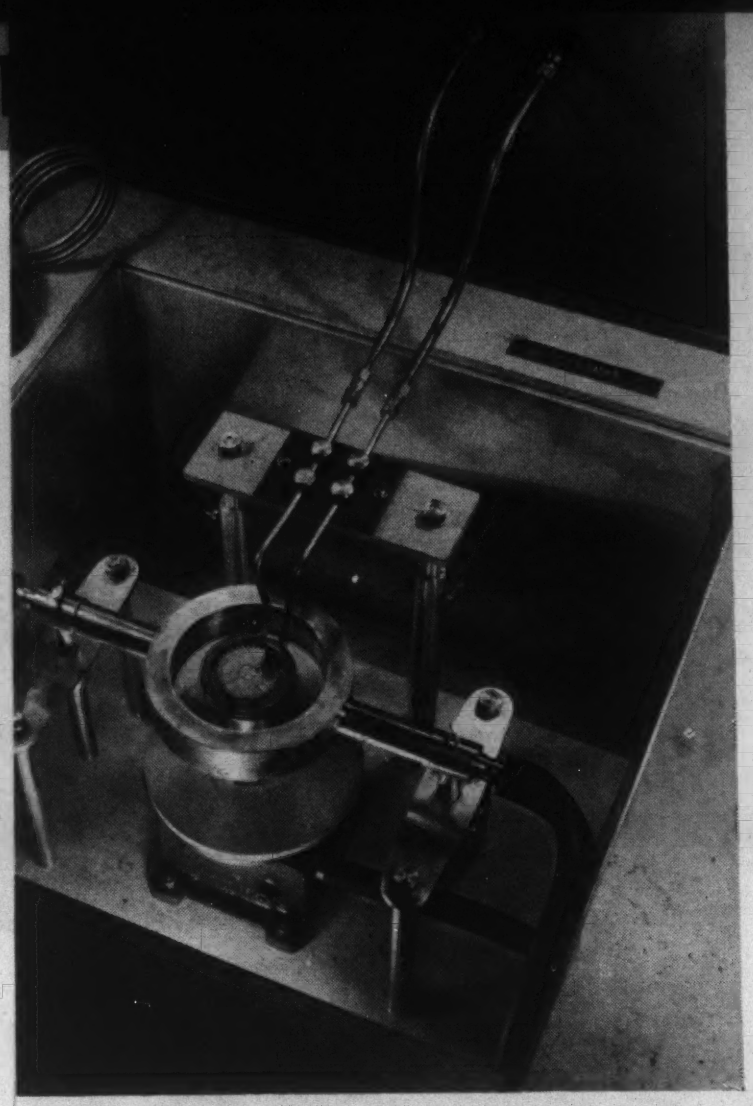
Induction heating controls the area hardened but heats at high cost. In some applications the work is heated in a furnace to a temperature a few hundred degrees below the hardening range, then is transferred to the induction equipment, and the area to be hardened is brought to hardening temperature rapidly, sometimes in less than one second. Quenching is automatic.

Jobs of this kind are being set up to harden one piece every second, including 0.7 sec. induction heating time and 0.3 sec. quenching and work handling time. Without the furnace preheat the induction equipment probably could not handle more than one part every 6 sec.

Two Equipments Combined

Sometimes the heating task is divided between two or more induction heating equipments.

In the hardening of a gear in which the tooth area alone is to be hardened but the exact areas and contours of hardening on the teeth are to be controlled very closely for the sake of stress engineering, an equipment of about 10,000 cycles is used to bring the tooth area up to a temperature close to the hardening range and an equipment of slightly less than 500,000 cycles then takes over and brings the selected areas up to the hardening range. Quenching is automatic.



Most often induction heating is thought of in connection with hardening. Here the quenching fixture surrounds the coil and work. (Courtesy: Lepel High Frequency Laboratories.)

Hardening is done in less than 1 sec. per gear. The lower cycle equipment pours the power and thereby the temperature into several gears at one time, these gears passing successively through the electromagnetic field of the inductor and accumulating heat as they travel. The heated gears then pass on into the inductor of the higher cycle equipment which is better able to control the areas that are heated to the hardening range.

Two different cycle ranges are used because, generally speaking, the lower the cycles the easier to apply large amounts of power but the higher the cycles the easier to control the areas hardened on contoured shapes.

For continuous annealing of strip steel, continuous heating for tin plating, for heating when the strip is to be hot so paint will dry quickly on it, as well as for continuous hardening of pipes and tubes and shafts and strip and other long length shapes, two or more equipments sometimes are used in sequence.

These equipments may or may not be of different cycles, but they quite often are of differing kw. capacities. The successive equipments and their inductors force more and more power and therefore temperature into the metal, the exact amount contributed by any one inductor being selected by the nature of the job. Usually the final temperature is reached only in the last inductor in the line. Sometimes the last one or two inductors merely hold the temperature reached in preceding ones so the temperature will be applied over that much more of the travel of the material and the material can travel at a higher speed while being held at the desired temperature for the necessary length of time.

Carbon Solution and Diffusion vs. Speed

In some metallurgical structures of steel and of malleable and of gray irons the carbon is reluctant to diffuse or to go into solution within the brief time that induction heating is desired to take place. Adequate hardening at high speed, then, is difficult.

One way of solving this problem is to heat the metal much hotter than would be done by other and slower processes. Sometimes the temperature is raised as much as 300 or 400 F above the upper critical range. Opinions differ as to whether it is the extra heat that causes the carbon to go into solution or the metal merely gets that much more time while losing its heat to the quench bath. Whatever the metallurgical reason, the method has been successful.

Another method is so to rig the induction heating equipment that more time at the hardening temperature is available. This sometimes requires the pouring of cooling water on the areas of the work piece which are not desired to be hardened and thus preventing hardening temperatures from being reached at them.

One malleable iron piece required 35 sec. at hardening temperature for the carbon to go into solution, yet induction heating was able to harden the desired areas and keep the others soft.

Further study of this problem by metallurgists will greatly extend the use of induction heating for some tasks.

Surface Hardening Without Quenching

A technique which is under much study is the applying of a very thin heated area by using high cycles with high power to obtain the thin area very quickly, then abruptly shutting off the power so the unheated metal beneath that area can conduct away the heat and accomplish quenching.

No actual examples of this being done under production conditions were observed while gathering data for this manual. But several equipment engineers have accomplished this on some steels under laboratory conditions, and it may be in actual use under production conditions.

Development of this method will greatly increase the use of induction heating where thin case hardening is required.

Varieties of Induction Heating Jobs

When parts are carburized but some areas are to be left soft those areas often are copper plated to prevent hardening. The success of the copper plating depends upon the sizes and shapes of the plated areas and the ability of the plating process to throw into them.

Parts which copper plating failed to protect often are salvaged by induction heating to soften the desired areas. Hundreds of such jobs are performed by shops which operate induction heating equipments on a jobbing basis.

When this happens frequently enough with a given part the copper plating operation can be discontinued and the induction heating used entirely. In many instances induction heating makes it economical to case harden parts which had been left soft.

Parts made of steels of closely controlled analyses often will expand or deform to highly predictable accurate dimensions if the heat treating is controlled carefully enough. Induction heating offers this close control, and is superior in control when only selected areas of the parts are to be hardened. Example: The threads of a lead screw are to act as a bearing upon which a sliding part travels. Induction heating hardens the crests of the threads only, holds them to close tolerances, causes no warping or distorting of the lead screw.

Induction heating offers to hardening rooms many operations for controlled drawing after hardening.

One large part is preheated throughout, either in a furnace or in a special induction coil, then its selected areas are rapidly heated above the hardening range, after which it is automatically quenched. The quenching is first by sprays carefully controlled in volume, velocity and direction of oil applied. Then the piece is lowered into a bath of controlled temperature and allowed to remain only until it has cooled slightly below the hardening range. Upon being withdrawn from the bath, heat from the main body of the piece enters the hardened

areas and performs the drawing operation.

In another example an inductor or "war head" traverses the interior of a cylinder, heats it to hardening temperature, and applies a quenching spray so the piece is progressively hardened. After this operation is completed the inductor again traverses the cylinder and applies a drawing temperature.

Induction heating usually acts so rapidly that no significant amount of scale is formed and no controlled atmospheres are necessary. But in extremely critical cases induction heating can be operated in controlled atmospheres with very little difficulty.

Annealing

Induction heating is capable of annealing parts with such rapidity and precision that no scale troubles are found. One result of this is that annealing operations often are added to production sequences. When stampings which previously had been left hard are induction annealed the dies and tools which perform secondary operations upon them will last longer.

Because of its ability to control the areas to which heat is applied induction heating is used for annealing some sections of hard pieces and not others. When such pieces are put into drawing presses for further operations they draw more readily at the softened than at the hardened sections. The shapes to which they are drawn can thereby be controlled. Waste and trim scrap is reduced, contours are so formed that the thickest and strongest sections are found at the areas of greatest stress, dies are simplified, machine set ups are made less costly, some secondary operations are eliminated by this method.

This technique also is used in bending and in stretching operations, and in rare cases in which steel shapes are to be twisted into spiral or other forms.

To facilitate the machining of thin or springy parts selective area annealing is used in conjunction with selective area hardening. The section of the piece which will be grasped by the chuck jaws is hardened for stiffness while the area to be machined is softened to reduce the physical strains of machining. After machining the piece may be run through the induction equipment either to anneal the hardened section or harden the annealed one.

Selective area annealing of heavy sections or of thin sections which are integral with heavy ones is a common induction heating application. It saves the heating of entire large pieces. Often this selective area annealing permits pieces to be made in solid forms instead of making several different pieces and then welding or brazing them together.

Induction heating is becoming a preferred method for annealing some parts made of the kinds of stainless steel which are subject to carbide precipitation and to consequent intergranular corrosion. In one case the annealing temperature is reached in less than 5 sec., allowing very little time for the material to dwell in the dangerous or critical temperature range. This is important. The time period during which the material dwells in the critical range is one of the governing factors of the amount of carbide precipitation which takes place.

Metallurgists have found that in some cases the high speed of annealing by induction heating methods permits annealing at higher temperatures with far less coarsening of the grain structure.

One automatic equipment of 100 kw. capacity and 9600 cycles is used for continuous annealing of stainless steel tubing. The tubing passes through a series of inductors, the last of which brings it up to 2000 F. The tubing passes on through a water cooled jacket, the heat being lost to this jacket by radiation and by convection through an air gap without the tubing having any physical contact with the jacket.

The equipment cost about $18,000 and required six months of experiment to get going. Of this cost about $10,000 was for the induction machine, $4,000 for the inductors and the work handling and the cooling equipment, and $4,000 for experimental costs not including engineering time. A second equipment probably could be installed for about $15,000, or for even less if no experimental work to improve the operation were undertaken.

The tubing travels at about 11 f.p.m. If higher speeds are attempted there are troubles with proper centering in the electromagnetic fields with consequent danger of uneven heating. The machine takes all tubing sizes from 1 to 4 in. and can be set up to change from one size to another in one hour or less. If there were no need to make these changeovers then the positioning equipment to permit higher travelling speeds might easily be developed.

The company may install equipment to anneal larger and smaller sizes. If so, a lower number of cycles will be used for tubing of over 4 in. diameter and a higher number for tubing of less than 1 in.

The great advantages of this equipment are the absolute dependability of each anneal, the high heating and cooling speeds which prevent carbide precipitation on any steel analyses subject to this, and the complete lack of scale. In the process of manufacturing, one length of tubing may be annealed ten or more times. This tubing is high priced and thin walled. Any unevenness of annealing, and especially any formation of scale, could cause high spoilage of the product.

Forging

More than $500,000 worth of induction heating equipment is reported to be in process of installation in a single forging shop. Even larger equipments will follow for forging applications.

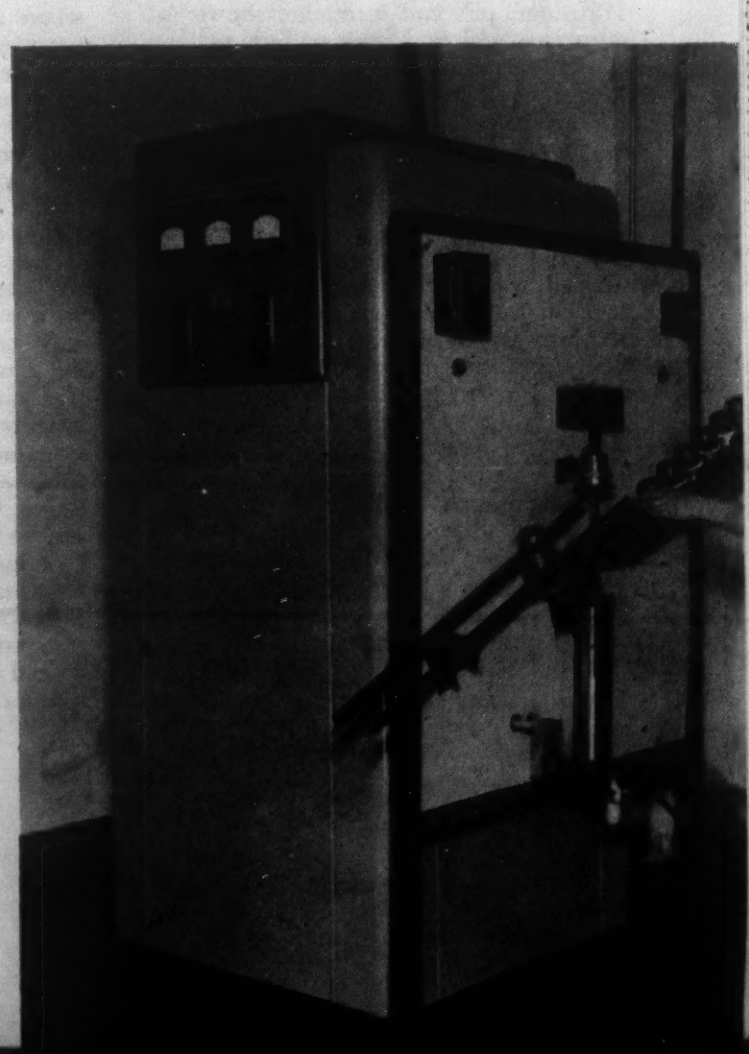
An installation of this size is specially engineered, as would be any machine tool installation of similar importance. Cycles, kw. capacities, timing, maintenance methods, work handling devices, interlocking controls, safety features, all are carefully integrated.

The induction heating equipment serves as the production speed governor of the entire shop. Hot pieces are delivered to the forging machines at exactly the speeds that they ought to take them.

This governor is infinitely variable. If anything happens to forging dies or to a forging machine so the machine has to slow down or stop then the operator can simply press a button and no more steel is heated for him. Or if the machines are so set up that he heats metal only when he presses the button then he refrains from pressing it. Thus there is no gambling on the question of whether to keep a large amount of steel hot and add to scale while fixing the forging machine or to let the metal cool and then reheat it. This question simply does not arise.

The operators work in far greater comfort, especially in hot weather. Therefore the familiar summer season slow down is not likely to occur.

Scale damage to dies is minimized if not eliminated. It is estimated that in forge shops this factor alone can increase die life by 200% to 300% or even more. The amount of useful steel is increased. A na-



This set-up for induction brazing uses an air unit to position and hold the work. (Courtesy: Allis-Chalmers Mfg. Co.)

tional study has indicated that in forge shops scale in the furnaces averages from 3.5% to 4% of the steel heated. The value of the metal saved by eliminating this scaling will pay for the induction heating power cost if the power is bought at one cent a kw. As an additional saving the machining and other finishing time on forgings often is reduced 50% when no scale is beaten into the forged surfaces by the forging machines.

The cost to set up forging machines can be reduced. By induction heating methods only one billet is heated to try the dies and another to reheat after touching them up.

In much smaller equipment induction heating also is used as a production speed governor. Constant streams of pieces to be heated and forged are fed through the inductors. They arrive at the dies at forging temperature, are fed and forged automatically, and the machines operate with no more care and attention than automatic punch presses.

This sometimes requires that the rods or other raw materials shapes from which the forgings are to be made be first cut into appropriate lengths. Automatic machines also can feed coils of wire or long length rods and the like.

Some parts require only that selective areas be struck by the forging hammers to impart the control of directional strength and the other qualities secured by forging. These parts also can be handled automatically, being induction heated only at the selected areas that are to be forged.

Forging requires through heating. And through heating of anything but very thin sections is the costliest form of induction heating. But in many cases the gains repay the costs, with profits. Case studies on some high alloy steels show as much as $30 per ton saved by elimination of scale.

Induction Heating as an Inspection Tool

Induction heating currents tend to concentrate at any areas of imperfection in the parts being heated, and to melt or otherwise mark these areas. Induction heating thus acts as an inspection tool. The imperfections act as shrink areas and their marking becomes unmistakable.

Porosities, pits and seams are shown up. The process will find folds or laps in forgings. If welded areas are induction heat treated after welding then any poor welds are likely to open. Unsound areas in castings may actually melt under induction heating which otherwise would merely heat treat the part.

Some highly special inspection operations are performed by induction heating. One of them is to find the exact amount of silver being deposited on steel balls for special ball bearings, the silver being intended to be only one monomolecular layer thick. A sample silver coated ball is placed in a glass flask, heavy vacuum is applied, an inductor is positioned outside the flask so the ball is within the electromagnetic field, the silver thus is distilled off within the vacuum, the silver then deposits on a cool area of the glass and is measured by photoelectric means.

Brazing and Soldering

Brazing, silver soldering, hard soldering, and soft soldering operations by induction heating run the gamut from extremely simple and off-hand work to highly complex and fully automatic.

Carbide tipped tool brazing often is done by off hand methods. If a broken or worn tip is on the shank then the tool maker removes this by holding it in the inductor for a few seconds and melting out the old silver solder. If necessary he can remill the bearing surface to remove any remaining solder. To apply a tip he fluxes the contact surfaces, puts on a piece of silver solder in sheet form, puts on the new tip and positions it carefully, places some asbestos board or wooden blocks in such position at the inductor that he can position the shank by resting it on them, positions the shank end within the inductor, holds down the tip with a wooden stick, and in a few seconds the operation is completed. It is a semi skilled task at best.

A more complex brazing operation costs a total of about $14,000 of which $5,000 was for the induction machine and $9,000 for work handling equipment and experimental costs. It required a full year for final development but was in operation in partially developed form long before that—an experience quite in line with the development of special work handling equipments of any kind.

When fully developed the installation brazed 600 complete assemblies an hour, and the equipment cost could be spread over a large number of pieces. When this task no longer is to be performed the heating machine will still be a $5,000 heating machine in good shape and most of the mechanical equipment can be converted to other uses.

This equipment required girls to flux the pieces, assemble them with cut-to-shape brazing alloy, and place them in a dial feed. Ejection was automatic.

Other equipment performs the fluxing and assembling operations automatically or semi-automatically, the parts being fed by means of hoppers and by automatic positioning and clamping mechanisms.

Induction heated soldering and brazing operations can approach but not equal the flexibility of torch operations in that, like the torch, the induction heat can be put where it is wanted and can be moved along progressively so as to "draw" the solder or the brazing alloy to the areas to be filled. It resembles furnace soldering and brazing in that careful compromises must be made in regard to the cutting and placing of the alloy so as to get exactly the right amounts in the right places, the selection and application of the flux, the tolerances and limits within which parts are made and thereby the accuracy with which they fit together or with which their surfaces are distant from each other when the heat is applied, and the gravity or clamping pressures with which the parts are pressed together while the brazing alloy or the solder is flowing.

Induction heating methods also resemble furnace methods in the neatness and cleanliness with which soldering and brazing can be done, and in the occasional need to redesign parts in order to promote assembling economies. Induction heating in many instances exceeds furnace methods in the ease, convenience and low cost with which special clamping and positioning mechanisms can be used.

One shop has a conventional brazing furnace with hydrogen atmosphere standing beside a conventional induction heating machine. Dozens of different soldering and brazing operations are performed on a production basis. About half of them are done most economically in the furnace, the other half in the induction equipment.

Induction heating is widely used for soldering metal to Kovar and to glass. In many cases the time as well as the temperature of heat application has to be carefully controlled lest the alloy enter too deeply into the pores of the glass or the Kovar with consequent rupturing or splitting of the finished part when in service.

Parts which are used for assemblies so critical that no surface oxidation whatever can be tolerated are placed in double walled glass flasks, the air is evacuated from the inner flask, cooling water is circulated between the walls of the flasks, an inductor is positioned outside of the outer flask and with loose coupling the part is heat treated within the vacuum. The inner flask then is sealed and the part is stored in vacuum until it is removed for assembly into the product.

Highly reactive metals are melted and cast in vacuum by the same method.

Shaped and machined shafts are examined for deviation from straightness and the crooked areas are marked. The machine operator places one shaft within an inductor in such position that only the desired area will be heated. The shaft heats up in about 20 sec. and is taken out and straightened in a straightening press. Two inductors are in alternate use so the operator is heating one shaft while straightening another.

A spindle which formerly was made with great difficulty in one piece now is made with much greater ease in two pieces which are silver soldered together.

The ends of the two pieces are induction heated in one position in a mechanism, and are quenched. The two pieces then are silver soldered together in a second position in the same mechanism.

Shear blades are made at reduced costs by making their main bodies of soft and common steels and applying inlaid edges made of hard materials. The inlaying is done by hammering, and for this the metals must be heated. An inductor precedes the hammer as the hammering operation traverses the length of the blade. The result is that heat is applied only as and when the hammering requires it, warping problems are eliminated, and no significant amount of scale is produced on the metal.

Induction heating equipments comprise a whole family of machine tools and probably have more diverse applications than any other machine tool family. Some are specially engineered throughout, others completely standard. They are in all sizes and capacities from very large to very small, and are capable of highly accurate operating control by widely diverse control mechanisms and devices. Some types have hardly entered on the first phases of their complete development stages. The market for them appears to be at least 90% undersold, especially in point of the number of factories using them. The induction heating equipment industry seems destined to grow much faster after the war than it did during the war. The biggest installations ever attempted with it are being made right now.

CONTENTS NOTED

A monthly department dedicated as a forum for the interchange of ideas between readers and editors. All readers are urged to take advantage of this space and participate in the discussions presented.

British Diamond Drawing Dies

To the Editor:

I was interested in the article "Diamond Dies for Wire Drawing" (MATERIALS & METHODS, March 1946) and thought your readers might be interested to know something of recent progress in Great Britain.

When France fell in 1940 it cut off the principal source of supply of diamond dies for fine wires (below 0.002-in. dia.). This caused to be launched a concerted drive to establish a British source. Methods of drilling fine dies have been revolutionized by work done in the Research Laboratories of General Electric Co.

The traditional French drilling machines were flimsy and inaccurate and required a craftsman's nursing to give even a passable product. The new machines developed are precision tools and can be operated by girls after a few weeks of training. The smallest die in Great Britain, drawing wire 0.00028-in. in dia., was made on a G.E. drilling machine.

In dies of the type used for copper and soft materials, the length of the parallel bearing is made equal to 30% of the diameter of the wire. For harder alloys, the bearing is made rather longer and the approach and the reduction angles are slightly reduced. For drawing bronze bearing length is equal to 50% of the diameter, and for nickel-chromium resistance wire and steel wire it may be equal in length to the diameter of the wire. For tungsten wires, however, British practice differs appreciably than that described in your article. In this case the die has a relatively short bearing, equal to 50% of the diameter and a very long entrance.

J. C. Chaston

Harrow, Middlesex,
England

We appreciate Mr. Chaston's comments on fine wire drawing. In an illustration sent with Mr. Chaston's letter was shown the difference in nomenclature used by the British and that used here. The cone in American terminology becomes a "bell." The secondary cone become "entrance" and "approach." A "reduction angle" precedes the bearing and after the relief portion of the die the British designate the area as "exit." According to Mr. Chaston, this is now standard British terminology and it is hoped to have the terms accepted throughout the world.—The Editors.

Easy to Handle Pickle

To the Editor:

We were surprised to read in the "Blueprints" section of June 1946 issue of MATERIALS & METHODS an article pointing out the need for a pickle shipped as a solid and changed to a solution at the plant with no obnoxious fumes being emitted.

Realizing that such a material was desirable, this company has been producing Ferrisul, an anhydrous ferric sulphate, for the past ten years. This product is readily available, and we would be glad to send complete details regarding it to any of your readers who might be interested.

F. Faxon Ogden, Manager,
Chemical Sales Development

Monsanto Chemical Co.,
Merrimac Div.,
Everett, Mass.

Our statement in "Blueprints" was not quite as behind the times as this letter might suggest, as the paragraph referred to told the reader to "look for" such a material. Fortunately, the reader does not have to look very hard,

(Continued on page 415)

Here Is Our Proposal:

MAKE A TON OF SHEET STEEL GO FARTHER—PRODUCE MORE GOODS

The Trend of American Industry Suggests the Method

This is not a radical idea. It is in keeping with an established trend in industry to adapt better metals to the job, and make them "pay their own way" through more efficient design and production. Sometimes the goal has been to improve product performance, eliminate excess weight, or simplify fabricating operations. Today, the primary goal of practically all metal-working industries is to *get more production—make a ton of steel produce more goods.*

High-Tensile Steels Provide the Way

High-tensile, low-alloy steels have the properties needed to attain this objective. By taking advantage of their higher yield and tensile strengths and great corrosion-resistance, designers can reduce sections as much as 25% in a wide range of applications now built of carbon sheet steel—and still retain the same strength and durability. Metallurgy takes the place of mass to boost production per ton of steel.

Our Estimate: One Extra Product for Every Three You Build

We have worked closely with manufacturers on the application of N-A-X HIGH-TENSILE steel for varied parts and products. We know what can be accomplished with this fine-grained, low-alloy steel. It is our estimate that production of units per ton can be increased as much as 33% by replacing heavier sections of carbon sheet steel with lighter sections of N-A-X HIGH-TENSILE. And because of the good formability of N-A-X HIGH-TENSILE, exceptional in such a high-strength steel, the change-over can be accomplished without serious problems in fabricating.

Our Challenge: Look at Over-All Costs

We also believe that the higher cost of N-A-X HIGH-TENSILE, compared to carbon sheets can be compensated by production economies, over and above the savings in steel effected by its high strength. Greater corrosion-resistance, freedom from age-hardening and embrittlement, and increased resistance to "set" when bent may reduce handling costs. Exceptional formability and other desirable characteristics of N-A-X HIGH-TENSILE make possible the elimination of intermediate annealing between draws in many cases. Also, finer grain structure and higher hardness produce a smoother surface texture when drawn or stretched, resulting in a saving of metal finishing or in a higher degree of finish when painted or plated. These and other manufacturing advantages of N-A-X HIGH-TENSILE can be utilized to make N-A-X HIGH-TENSILE "pay its own way" on the basis of *over-all costs.*

We would like to work with you on your problems. We believe N-A-X HIGH-TENSILE will produce one extra product for every three you build.

MAKE A TON OF SHEET STEEL GO FARTHER
Specify—
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HIGH-TENSILE STEEL

GREAT LAKES STEEL
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N-A-X ALLOY DIVISION • DETROIT 18, MICHIGAN
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CONTENTS NOTED

(Continued from page 413)

for here is the answer. Seriously, "Blueprints" is intended to bring news of developments in their earliest stages and it is seldom that we report on materials or processes that are in production. We thank Mr. Ogden for putting us straight on Ferrisul.—The Editors.

Hipersil Flux Densities

To the Editor:

In your issue of January 1946, page 89, you state that . . . "recent advances have further improved its magnetic properties, so that today Hipersil gives 20 to 30% higher flux densities than ordinary hot-rolled silicon steel, and therefore permits a 20 to 30% reduction in core cross-section." That this statement is incorrect can readily be seen if we consider an extreme example. If a material were available which could be subjected to double the flux density of ordinary hot-rolled silicon steel we would then have 100% higher flux density, but a 100% reduction in core cross-section would leave us with no core at all. Actually, 20 to 30% higher flux densities would permit 16⅔ to 23.1% reduction in cross-section.

Irving B. Lueth

Chicago 26, Ill.

Mr. Lueth's points are well made. Our statement might better have read as quoted above with this additional statement following: . . . "for a given total of flux. That is, for a weight of core a considerable increase of capacity will be provided by the recent improvements in Hipersil." The comparison is best made in terms of a given total of flux rather than a given cross-section of core.—The Editors.

MATERIALS & METHODS Manual No. 16

To the Editor:

A big bouquet for another editorial masterpiece!

I'm speaking of Manual No. 16 in the June issue of MATERIALS & METHODS, which just came across my desk.

So timely, interesting and practical has it proved that I could not help but take time out from my normal work in order to send you these few lines to convey one reader's compliments for and appreciation of a job well done.

Unless I miss my guess, I'll bet most anything that this Manual is quickly becoming, if it hasn't already, one of the most popular you've published in this outstanding series.

It's bound to be a big help to all your readers, I think. Anyway, thanks for the best "short order course" on modern engineering materials and processing methods I've taken in a mighty long, long time.

Arthur P. Schulze

Taber Instrument Corp.,
N. Tonawanda, N. Y.

We are pleased that the long hours spent in preparing the review and directory of processing equipment has been well worth the effort. The comment of Mr. Schulze and many other readers is appreciated.—The Editors.

Gray Iron Castings for High Temperature

To the Editor:

Re your review of steels and irons in January issue of MATERIALS & METHODS:

The major part of our volume of business consists of the manufacture of gray iron castings and, consequently, we are interested in your article on a gray iron that can resist loads of 10,000 psi. at 750 F without creeping more than 1% in 10,000 hr.

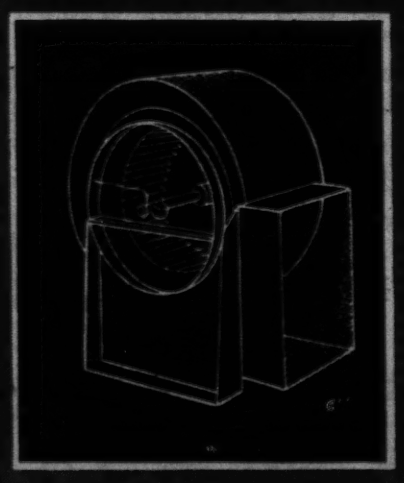
I will appreciate any additional information regarding the analysis and method of manufacture.

George W. Smith

Paxton-Mitchell Co.,
Omaha, Neb.

The information in our general review article about high temperature uses of gray iron castings came from C. O. Burgess of Union Carbide & Carbon Research Laboratories and T. E. Barlow of Battelle Memorial Institute, who published a paper on this subject. The paper presented a complete survey of high temperature uses of cast iron and discussed the inadequacies of present-day codes limiting its use. Copies of the paper are probably available from the secretary of the American Foundryman's Association, 222 W. Adams St., Chicago 6, Ill.—The Editors.

Mr. Big takes



TWICE THE ATMOSPHERIC CORROSION RESISTANCE of regular steel at an additional cost of only 5%... This simple fact explains why many designers specify U-S-S Copper Steel for ventilating equipment, ductwork, metal cabinets, machinery guards, and other applications where rust is a problem.

GREATER PASSENGER CAPACITY, a one-third increase in vehicle miles operated, and a 28% cut in operating costs are results reported by a New England transit company with trolley busses built of U-S-S COR-TEN High Strength Steel. If your product requires a high strength-weight ratio plus exceptional corrosion resistance, check COR-TEN.

MATERIALS & METHODS **Engineering File Facts**

NUMBER 118
August, 1946

MATERIALS: Cemented Carbide Tool Materials

A Comparison of the Various Grades of Cemented Carbide Tool Materials

The standard grades of cemented carbide tool materials made by seven of the leading manufacturers are compared in this *Engineering File Fact*. This comparison will show only the generally equivalent grades; there are specialized applications and unique conditions that are not included in this chart. The appropriate grades of carbide tool materials are given for each of the common machining operations according to the type of material to be machined.

There are, of course, other important industrial applications for cemented carbides besides cutting tools: balls for check valves, burnishing and for hardness (Brinell) testing; seats for valves; wear-resistant inserts; gages; bushings; etc. These are not included in this comparison.

This information was furnished by seven manufacturers whose products are listed below.

Material To Be Machined	Job	Grades[11]						
		Carboloy[1]	Delloy[2]	Firthite[3]	Kenna-metal[4]	Talide[5]	Vascoloy[6]	Willey[7]
Steel	Heavy duty roughing and interrupted cuts; for machining with relatively low speeds and heavy feeds (forged or rolled steels)	78C	TS-81	T-04 or T-83	KM	S-88	EE, 3150 or XX	710
	For heavy duty machining of steel castings	78C or 78B	TS-81 or TS-8	T-04 or T-83	K2S	S-88 or S-90	EE, EM, 3150 or XX	710
	General purpose machining	78B	TS-8	TA or T-89	KM or K3H	S-90	EM or X	606
	Finish machining	78	TS-18	T-16, T-31 or T-90	K3H or K4H	S-92	E	509[10]
	Precision boring	78, 883 or 831	TS-18	T-16, T-31 or T-90	K3H or K4H	S-92	E or EH	509
Cast and Malleable Iron	Heavy duty roughing and interrupted cuts	44A	TC-71	HA, H or HC	K2S	C-89	2A68 or 2A3	E-8
	General purpose machining	883	TC-7	HA or HE	K6[9]	C-91	2A68 or 2A5	E-6
	Finish machining	905, 999 or 907	TC-17	HA or HF	K6[9]	C-93	2A5, 2A7 or 2A9	E-6 or E-5
Brass and Bronze	Heavy duty machining including interrupted cuts	44A	TC-71	HA, H or HC	K6	C-89	2A68 or 2A3	E-8
	General purpose machining	883	TC-7	HA or HE	K6	C-91	2A68 or 2A5	E-6
	Finish machining	905 or 999	TC-17	HA or HF	K6	C-93	2A5, 2A7 or 2A9	E-6 or E-5
Aluminum and Magnesium Alloys	Heavy duty machining including interrupted cuts	44A	TC-71	HA, H or HC	K6	C-89	2A68 or 2A3	E-8
	General purpose machining	883	TC-7	HA or HE	K6	C-91	2A68 or 2A5	E-6
	Finish machining	905, 999 (or 907[8])	TC-17	HA or HF	K6	C-93	2A5, 2A7 or 2A9	E-6 or E-5
Monel	General purpose machining	883	TC-7	HA or HE	K3H	C-91	2A68 or 2A5	E-6
Nonmetallics	Heavy duty machining	44A	TC-71	HA, H or HC	K2S	C-89	2A68 or 2A3	E-8
	General purpose machining	883	TC-7	HA or HE	K6	C-91	2A68 or 2A5	E-6
	Finish machining	905 or 999	TC-17	HA or HF	K6	C-93	2A5, 2A7 or 2A9	E-6 or E-5

[1]Carboloy is the trade name of the carbide products made by the Carboloy Co., Inc., Detroit 32, Mich.
[2]Delloy is the trade name of the products made by the Delloy Metal Corp., Philadelphia 25, Pa.
[3]Firthite is the trade name of products made by Firth Sterling Steel Co., New York 13, N. Y.
[4]Kennametal is the trade name of products made by Kennametal, Inc., Latrobe, Pa.
[5]Talide is the trade name of products made by the Metal Carbides Corp., Youngstown 5, Ohio.
[6]Vascoloy is the trade name of products made by the Vascoloy-Ramet Corp., North Chicago, Ill.
[7]Willey's Carbide Tool Co., Detroit, Mich.
[8]Recommended for some precision finishing jobs on aluminum and magnesium alloys.
[9]For general use when machining malleable iron, grades K4H or K6 are recommended.
[10]For finishings when feed is greater than 0.005 in., grade 606 is recommended.
[11]When two or more grades are suggested for a particular type of job, they are listed in the order of increasing hardness and abrasion resistance (and in order of decreasing toughness).

Compiled by Robert S. Burpo, Jr., Associate Editor

N·B·M's "Man from Mars"

GIVES YOU CLEANER BRONZE CASTINGS ...CUTS MACHINING COSTS

This weirdly-clad gentleman is an "efficiency expert" in disguise. His skillful sand-blasting gives every N-B-M casting a clean, sand-free surface that doesn't dull cutting tools.

Result: faster, more efficient machining—another time- and money-saving advantage of N-B-M Bronze Parts.

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MATERIALS & METHODS Engineering File Facts

NUMBER 119
August, 1946

METHODS: General Engineering Data

Conversion Factors - European to U. S. Engineering Units

There is an increasing flow of European technical papers to this country as a result of the gradual resumption of research and industrial activity abroad and as an outcome of reparations agreements (part of the German reparations due this country are in the form of scientific and engineering information to be published here as soon as translations can be made).

In most of the foreign papers and journals, even if they are translated into English, the European (metric) units and quantities are used. For this reason, a ready reference table of conversion factors will be useful to readers who wish to convert the metric engineering units into those commonly employed in the metal working industry in the United States of America.

	To Convert From	To	Equations for Conversion	Abbreviations and/or Remarks
Length	Microns	Inches	(Microns) x 0.0000394 = (In.)	
	Millimeters	Inches	(Mm.) x 0.0394 = (In.)	Millimeter = mm.
	Centimeters	Inches	(Cm.) x 0.394 = (In.)	Centimeter = cm.
	Kilometers	Feet	(Kilometers) x 3281 = (Ft.)	Kilometer = km.
Area	Square millimeters	Square inches	(Sq. mm.) x 0.00155 = (Sq. in.)	Square millimeter = $mm.^2$ or sq. mm.
	Square centimeters	Square inches	(Sq. cm.) x 0.155 = (Sq. in.)	Square centimeter = $cm.^2$ or sq. cm.
Volume and Capacity	Cubic millimeters	Cubic inches	(Cu. mm.) x 6.1×10^{-5} = (Cu. in.)	Cubic millimeter = $mm.^3$ or cu. mm.
	Cubic centimeters	Cubic inches	(Cu. cm.) x 0.061 = (Cu. in.)	Cubic centimeter = $cm.^3$ or cu. cm. (1)
	Liters	Cubic inches	(L.) x 61.0 = (Cu. in.)	Liter = l.
	Liters	Gallons	(L.) x 0.264 = (Gal.)	
Weight	Grams	Ounces	(G.) x 0.0353 = (Oz.)	Gram = g. or grm.
	Kilograms	Pounds	(K.) x 2.21 = (Lb.)	Kilogram = k.
	Tons (4) (metric)	Pounds	(Tons) x 2205 = (Lb.)	
	Tons (British)	Pounds	(Tons) x 2240 = (Lb.)	
Density and Concentration	Grams per cubic centimeter	Pounds per cubic inch	(G. per cu. cm.) x 0.0361 = (Lb. per cu. in.)	Grams per cubic centimeter = $g./cm.^3$ or g./cu. cm.
	Grams per cubic centimeter	Ounces per gallon	(G. per cu. cm.) x 133.5 = (Oz. per gal.)	
	Grams per liter	Ounces per gallon	(G. per l.) x 0.134 = (Oz. per gal.)	Grams per liter = g./l.
Load Concentration and Pressure	Kilograms per square millimeter	Pounds per square inch	(K. per sq. mm.) x 1422.3 = (Lb. per sq. in.)	Tensile and yield strengths are usually measured in $kg./cm.^2$
	Kilograms per square centimeter	Pounds per square inch	(K. per sq. cm.) x 14.22 = (Lb. per sq. in.)	
	Tons per square inch (2)	Pounds per square inch	(Tons per sq. in.) x 2240 = (Lb. per sq. in.)	British practice is to report stresses in $tons/in.^2$
Temperature	Degrees Centigrade	Degrees Fahrenheit	(C) = 0.556 (F — 32)	Degrees Centigrade = C
	A range of degrees Centigrade	A range of degrees Fahrenheit	(C range) x 1.80 = (F range)	For example: ±5 C is equal to ±9 F
Impact Values	Kilogram-meters per square centimeter	Foot-pounds	Kg.-m. per sq. cm.) x 5.063 = (Ft.-lb.)	German impact data are reported in $kg.-m./cm.^2$ (3)
Work or Energy	Kilogram-meters	Foot-pounds	(Kg.-m.) x 7.23 = (Ft.-lb.)	Kilogram-meter = kg.-m. (5)

(1) *Also cc. or ccs. is an abbreviation for cubic centimeters*

(2) *British tons*

(3) *German impact data is obtained in kg.-m. and reported in $kg.-m./cm.^2$; this means dividing the kg.-m. figure by 0.7 if the standard DVM (Charpy) test bar is used; (H. W. Gillett & F. T. McGuire, Behavior of Ferritic Steels at Low Temperatures: Part I, p. 42, 1945, ASTM.)*

(4) *Also spelled "tonnes"*

(5) *Sometimes written "m.-kg."*

Compiled by Robert S. Burpo, Jr., Associate Editor

DEPENDABLE WELD METAL... born in the flash of an arc

Deposited alloy weld metal must be right *the first time.* The steel melter pours a test coupon, has an analysis made, and then corrects for variations in composition. The welder has to melt, alloy, flux and pour his weld metal in the split seconds during which the electrode is converted into weld metal.

Every Arcos Alloy Electrode is a completely balanced charge . . . ready to be released at the striking of an arc . . . depositing EVERY TIME, weld metal as chemically and metallurgically correct as the alloy steel made by the melter.

When so much depends on so little . . . weld stainless with Arcos!

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engineering SHOP NOTES

Metal Forming with Carbide Dies

by Earle Glen,
Carboloy Co., Inc.

Only in the last few years have carbide dies begun to see wide use in metal forming operations. Carbide blanking and laminating dies, and dies for both heading and cold nosing were practically unknown in industry in 1940.

The major advantages attributed to the use of carbide dies are: (1) longer service life than comparable steel dies, (2) less servicing of the dies required, (3) increased production, (4) better surface finish imparted to the formed parts, and (5) the total number of required drawing operations is usually less.

Carbide dies are useful for deep drawing operations on sheet metal. Here is shown a carbide die used in the production of high pressure cylinders.

Until 1940, the largest carbide die for deep drawing sheet was about 4 in. I.D.; the largest tube drawing dies and mandrels were 3 and 1½ in. dia., respectively. Dies for deep drawing up to 13½ in. can now be used.

Since a carbide nib of this size weighs more than 100 lb., special techniques for the production of such large dies have had to be developed. One such is the "hot press" method in which the three major operations of pressing, semi-sintering and sintering are combined in a single operation. Metals which can be drawn on these carbide dies include plain carbon steels, special alloy steels, brasses, bronzes, copper, aluminum alloys, zinc alloys, lead and tin.

A typical example of deep drawing operations with carbide dies is in the production of high pressure cylinders for fire extinguishers and storing commercial gases. The I.D. of the dies range from 2 in. to 13½ in. The completed gas containers run from 2 in. dia. by 6½ in. long to 8¼ in. dia. and 32 in. long. Alloy steels such as stainless and chromium-moly, plain carbon steels and aluminum alloys are used. The stock is 0.440 in. thick before drawing.

Application of carbide punches and dies to blanking and laminating has been accomplished on blanking steels and other metals in thicknesses up to 0.025 in., in rounds and simple shapes. Typical lamination die practice is in the manufacture of stators for electrical motors where laminations are punched out of sheet metal at single step index machines.

In tube drawing the diameter of tubing drawn through carbide dies has been upped to 6 in. Steel rocket tubing is an example. The entering size of the tubing was 5 9/16 in. O.D. and was cold drawn down to an O.D. of 5.035 in. and a wall thickness of 7/32 in.

Nailing Tags on Steel Ingots

by William J. Long,
United States Steel Corp.

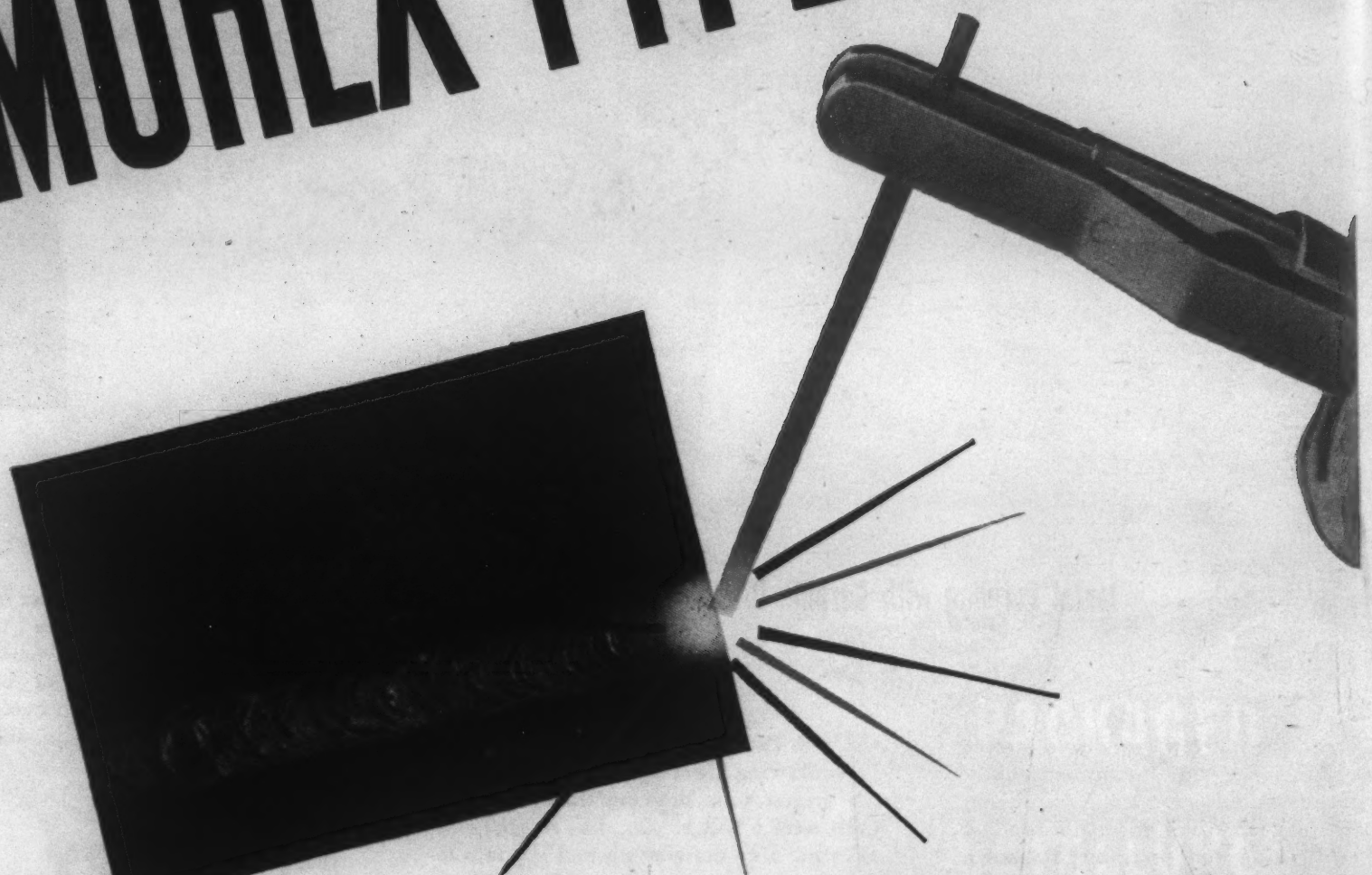
A method has been devised to do the seemingly impossible job of nailing identi fication tags to cold ingots of the hardest steel.

Not only can nails be driven into cold steel, but it can be done with very little effort. A 2¾-lb. hammer with a simple spring attachment to hold the specially heat-treated, quarter-inch nail, made by American Steel & Wire Co., and metal tag bearing the heat number is all that is required. Furthermore, exceptional physical strength on the part of the man wielding the hammer is not necessary.

Originally conceived at one of the U. S. Steel Corp's. eastern plants several years ago, the idea was tried at the South Chicago mill recently when an identification procedure survey was being conducted. After several experiments the original hammer was redesigned and a new device developed for holding the tag and nail to allow the whole operation to be done with one blow.

The improvement was successful, and soon ingots enroute to rolling mills from steel-making furnaces will be identified much more speedily and permanently than heretofore when a special paint was used.

MUREX TYPE HTS



The Right Electrode for Hard-to-Weld Steels

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MUREX ELECTRODES

Silver Flake Paints

by Alexander F. Knoll,
Metals Disintegrating Co., Inc.

Although of high initial cost, the use of noble metals—gold, silver, and platinum—in certain processes or articles may lead to considerable saving because of reduced labor costs. In the mass manufacture of small, precision electrical condensers, silver-coated mica laminations have replaced to a great extent the laboriously prepared mica, metal foil laminations formerly used.

Sheets of small laminations are prepared by spraying over a mask or printing silver films on the dielectric surface. The paint also carries a silicate glaze to fix the silver particles firmly to the surface of the dielectric. Condensers of the desired capacity can be made by cutting the lamination to size and stacking the proper number.

During the war silver flake was found to have advantages in this use over the older granular silver powder or oxide. The flaky structure of the particles results in more complete coverage of the dielectric with less silver, thus allowing each laminar unit to hold a higher charge, allowing saving in silver and dielectric material.

Silver flake powder is a silver powder of low apparent density and can be used as a substitute for granular silver in certain powder metallurgical processes where a low density powder is required. Its flake character suggests its use in place of copper flake in some molded parts, where high chemical resistance and superior electrical conductivity is required. The substitution of silver for copper in certain uses during the war has demonstrated that a low cost does not necessarily follow a low price.

Silver flake paints have been used in the decorative arts also. Ceramic paints, luxury inks, and paper coatings have been used to achieve artistic effects. Another suggested use for silver flake paints is in specialty brazing.

—Courtesy of "The Drum"

Broaching Fixture for Vertical Machines

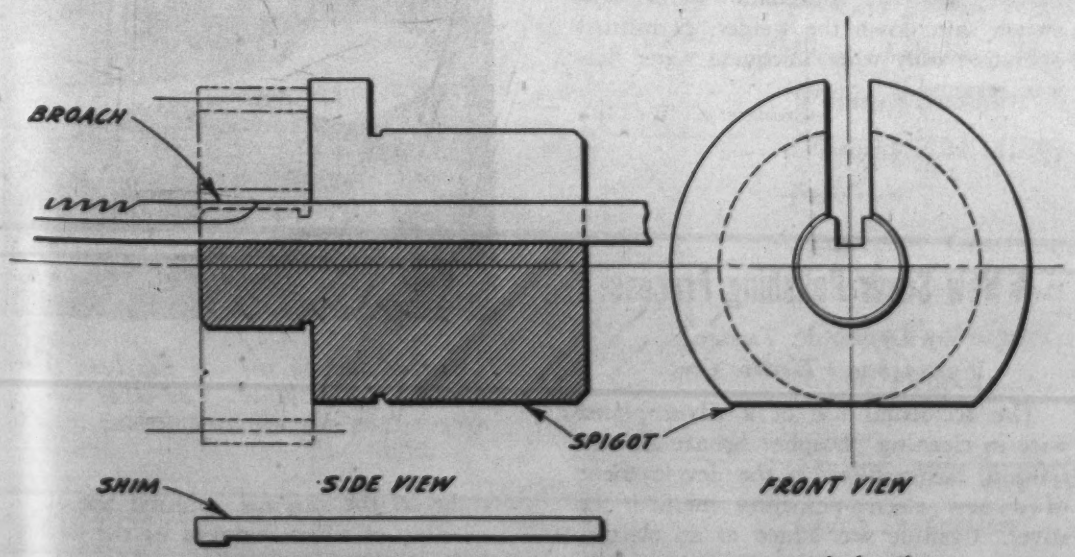
by Thomas A. Dickinson

Most broaching can be accomplished without special fixtures, a hardened bushing which fits into a hole in a machine table being all that is generally necessary. However, on vertical machines it is sometimes preferable to slide the work over the leading edge of the broach; in such cases, fixtures are desirable.

The accompanying diagram shows a fixture which has served the latter purpose for Consolidated Vultee Aircraft Corp., San Diego, Calif. It is a spigot-type broaching fixture whose rear portion may be fitted into a hole in a machine table, and whose flat undersurface is positioned against a shoulder or plate, thus preventing any movement.

A component (represented by phantom lines) is push-fitted over the front end of the fixture; the bottom of the groove within the fixture controls the depth of the keyway — since the total depth of the groove plus the depth of the keyway equals the maximum depth of the broach at its largest end. If a hardened shim is placed in the bottom of the fixture groove, it is possible to cut a keyway deeper than the total cutting depth of the broach.

A lip on the shim should bear against the end of the spigot and keep the shim from being pulled through the slot by the friction of the broach.



A drawing of the broaching fixture showing the essential details.

In tropical regions there is a fungus capable of corroding glass. A simple moisture-proof hood to protect microscope lenses and similar glass optical instruments has been devised at the Federal Experiment Station at Mayaguez, Puerto Rico. The hood is made from sheets of cellulose acetate film. Three light wire hoops are attached to the inside of the hood with adhesive tape. To make a seal a small circular groove in the wooden base is filled with mercury. A dish of calci m chloride is placed under the hood to absorb moisture. The hood is more convenient and cheaper than a glass bell jar.

—Foreign Commerce Weekly

Tips on Cleaning of Zinc Die Castings

by C. H. Jeglum,
Philadelphia Quartz Co.

In the plating of die cast parts cleaning prior to the plating operation is an important step. Failure to remove a tiny oil spot may cause the plating to peel; the redeposition of removed dirt of any sort is likewise detrimental.

Cleaning of die castings is usually done electrolytically. The metal castings are connected to electrodes and hung in baths of industrial detergents (which serve as the electrolyte) while a current, carefully controlled as to voltage and amperage, passes through the cell. Sometimes the castings are used as cathodes, sometimes as anodes, and it is not uncommon to reverse the current so that the casting acts as both.

Sodium silicates are among the alkalies used for this cleaning work. Recently, after failures in one operator's plating rooms were reported, tests were conducted to solve some of the problems entailed in the use of sodium silicates.

One of the questions to be answered was the effect of various silicate ratios. Accordingly, tests were run with 3% solutions of sesquisilicate, metasilicate, disilicate and trisilicate. Results were that with the disilicate and trisilicate a heavy white deposit of noncrystalline material almost completely covered the metal while the other two silicate ratios left a bright or specular surface.

In the tests the specimens which served as cathodes retained the brilliance of the original. It was only on the anodes that the high silica solutions formed the deposit. It is clear, therefore, that zinc die castings should not be cleaned anodically in detergents; also, that meta- or sequisilicates are satisfactory for cleaning zinc die castings while di- or trisilicates are not.

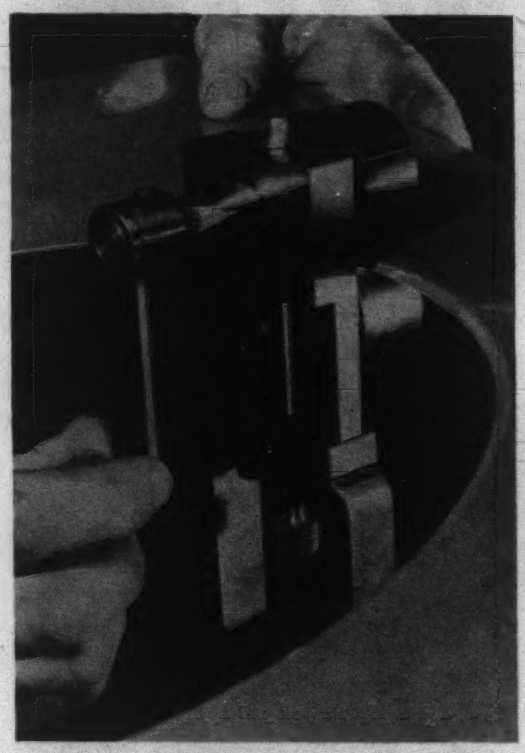
Further tests indicated that at a temperature of 175 to 195 F and with a concentration of 3%, sodium metasilicate will form no deposit and will not attack the metal. In general, lower temperatures increase the chance for anodic deposits, and higher concentrations may cause darkening of the anode. High current density also increases the tendency to form deposits.

—Courtesy of "Silicate P's & Q's"

Sheet Metal Crimper

by Frank Lucorelli,
The Glenn L. Martin Co.

An ingenious device with which sheet metal up to 16-gage may be crimped either at the bench, on the job or after installation, has been developed at The Glenn L. Martin Co. plant. The tool will work equally well on straight edged metal, sheets or pieces curved to any shape, on the inside of blanked-out holes, or wherever crimping on sheet metal may be required.



Shown in operation is the new tool developed for crimping sheet metal up to 16-gage on the job or after installation.

In its general shape, it is not unlike the familiar can opener attached to the kitchen wall or a tool used by shoemakers to crimp pieces of leather together. Two round dies, one with a projecting edge, the other rounded to fit, are held together by spring tension and an adjustable screw to fit them for various thicknesses of metal.

Turning a crank pulls the metal sheet between the dies. Held firmly against a guide, the edge of the metal is crimped to the desired shape. The tool may be operated by clamping it in a bench vise, probably its most widely used place. By substituting a wheel for the conventional handle (with little sacrifice in leverage) it also can be used right on the piece needing crimping after it has been installed in the airplane or other assembly.

Rachet wheels may be installed in the device so that there is no slipping, because, being small and handling only the thinner sheets of metal, the gears will not unmesh sufficiently to become separated.

One of the most important factors is that of safety, when compared with previous methods of hand crimping. Most of these required a tool looking somewhat like an oversized pair of pliers which was literally pulled around the edge of the metal by sheer strength. Having no stationary guide, the device did not always give a satisfactory crimp. It also was dangerous, as the tool sometimes slipped off under the pulling necessary to make it operate.

After resistance welders have been in service for some time there may be indications of a loss of secondary power. The capacity of the welder will appear to have dropped. This usually is caused by loosening up of the joints in the secondary electrical circuit, oxidation, or both. The joints should be taken apart, pickled or thoroughly cleaned, such as rubbing with fine emery paper, then carefully fitted up again. It may be wise to silverplate the contacting faces of all joints including both sides of the strips forming the flexible bands. This can be done by brush plating, a method used by many job plating shops.

—"Weld-It,"
Taylor-Winfield Corp., Warren, Ohio

Cooling Electronic Contactors on Resistance Welders

by C. E. Schwartz,
The Taylor-Winfield Corp.

When electronic contactors are used with welders, a common cause of maintenance trouble is lack of sufficient cooling water through the power tubes. Insufficient flow causes this water to overheat, actuating the flow switch which in turn opens the firing circuit to the ignition tubes. This automatic feature is a protection against shortening the life of the tubes.

In making a water connection, care should be exercised to assure a constant flow of cool water. A welder should not be put on a water line with other pieces of equipment which may cause pressure variations.

In one case, by way of illustration, a welder was placed on a lavatory water line. Each time the lavatory was used the water pressure dropped. The water overheated and the automatic water flow switch shut down the welder, permitting operation only when adequate water flow was restored.

—Courtesy of "Weld-It".

A New Silver Polishing Process

by Dennis R. Turner,
Westinghouse Electric Corp.

The accidental use of a silver plated wire in cleaning phosphor bronze electrolytically has resulted in the development of a new electro-polishing method for silver. Cyanide was added to an electrocleaning solution when dime-size phosphor bronze diaphragms for microwave tubes proved particularly difficult to wash. One of the diaphragms had been suspended in the bath, through which alternating current was passing, by a strand of wire previously used to immerse some object being silver plated. The wire was a dull white in appearance as silver plate always is before being polished. But when the phosphor bronze diaphragm was lifted out of the solution, the piece of wire had taken on a high luster.

In the conventional method, metal articles to be silver plated are immersed in a bath of silver cyanide plating solution and negative current sent through. When they are removed from the bath, they are evenly plated with silver but are white and lusterless. They must be buffed by hand on a revolving wheel treated with some sort of buffing compound to impart the necessary shine. .

With the new method, the silver plated object is immersed in a bath of silver cyanide solution normal to the regular plating operation. Instead of sending negative current through the bath as in plating, however, positive current is applied in about four times the amperage used to plate the metal, but not continuously. The positive energy is applied for a few seconds, discontinued, then sent through again, and this intermittent action repeated for several cycles. When the article has reached its peak of luster, it is taken out of the bath, rinsed, and dried. The entire operation takes little more than a minute.

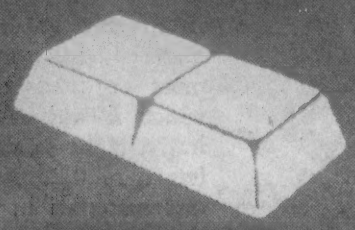
So that the current is applied and interrupted at the proper and regular intervals, a small motor is used with a switch that opens and closes a contactor to send along the intermittent flow of energy.

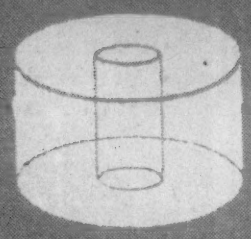
Although this electrolytic polish can be affected just as well by employing a plain cyanide solution, the more practical way is to utilize the same silver cyanide bath used to plate the objects, rather than having to transfer them to another tank containing only cyanide.

Ideal industrial practice would be to immerse the metal pieces—many at a time—send through negative current to silver plate them, then intermittent positive charges to attain the bright finish—all in the same bath. Besides eliminating the whole buffing process, this procedure would have the advantage of retaining

The teaspoon on the top has been silver plated but not shined. The other has undergone the new electro-polishing process.

right in the original solution the small quantity of silver removed by the electrolytic action of the cyanide while polishing.





Edited by **Robert S. Burpo, Jr.**

Associate Editor,
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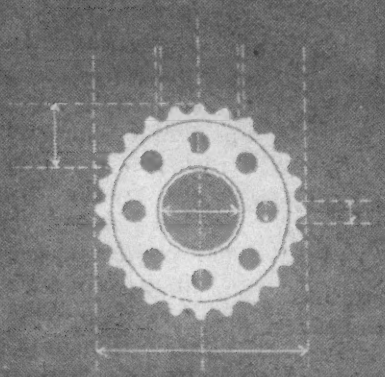

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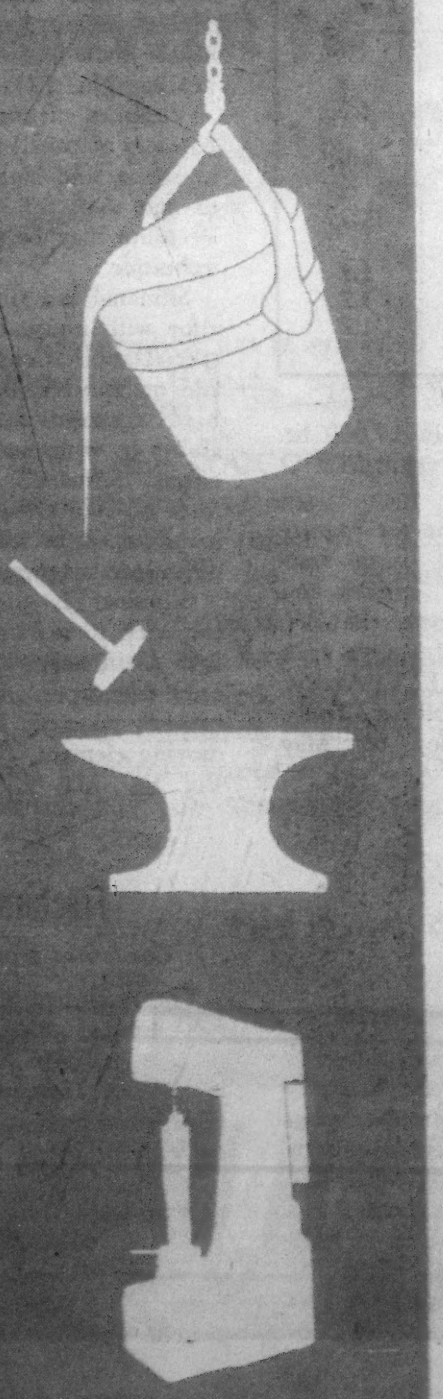

MATERIALS & METHODS

DIGEST

A selection of outstanding articles on engineering materials and processing methods in the metal-working industries.

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METALS and ALLOYS

Engineering properties and applications of carbon, alloy and stainless steels, irons and nonferrous metals and alloys. Selection and evaluation of metallic materials for engineering service. New alloys and modifications.

High Temperature Strength

Condensed from "Transactions" of the American Society of Mechanical Engineers

Data were obtained on the stress rupture characteristics of various steels in steam atmospheres to give the information needed by designers of high temperature steam equipment:

Type of Steel	Stress in P.S.I. for Rupture in 10 Hr.	1000 Hr.	10,000* Hr.	Steam-Air Ratio**
0.16% C	13,500	6,900	4,900	3.6
C — 0.5% Mo	21,500	8,600	5,450	1.8
2¼% Cr — 1% Mo	17,000	9,400	7,000	1.2
5% Cr—0.5% Mo—0.5% Ti	11,500	6,700	5,000	0.98
5% Cr—0.5% Mo—1.6% Si	15,500	7,600	5,300	1.2
9% Cr—1% Mo—0.7% Si	13,200	8,500	6,800	1.1
12% Cr	19,500	12,000	9,400	3.2
18% Cr — 8% Ni	35,000	16,800	11,600	1.2
25% Cr — 20% Ni	25,000	11,200	7,550	1.4

* extrapolated

** ratio of stress for rupture in 10,000 hr. in steam to stress for rupture in 10,000 hr. in air

There was a straight line relationship between stress and the rupture time with no break, as is observed in tests in air. The type and characteristics of the scale formed affect the position of the stress rupture line.

The amount of corrosion depends mainly on the chromium content. The chromium-free steels showed serious corrosion; the 2¼ and 5% chromium steels, appreciable corrosion; the 9 and 12% chromium steels, slight corrosion; and the 18 and 25% chromium steels very slight corrosion.

The ductility, as indicated by elongation, tended to decrease as the time for rupture increased. The occurrence of brittle fractures was favored by lower stresses and longer rupture times. However, the austenitic alloys showed brittle fractures even after short rupture times. (J. T. Agnew, G. A. Hawkins & H. L. Solberg. *Trans. Am. Soc. Mech. Engrs.*, Vol. 68, May 1946, pp. 309-315.)

Permanent Magnet Materials

Condensed from "The Iron Age"

Carbon-free alloys of such composition as iron-beryllium-nickel, iron-tungsten, and iron-molybdenum, when properly heat treated, have interesting permanent magnet properties that equal those of some of the quench-hardened permanent magnet steels.

Alnico magnets are, in general, alloys of nickel, aluminum, cobalt and iron of various compositions and treatments, made either by sand casting, precision casting, or sintering. They are hard, comparatively brittle, and nonmachinable. Complete magnetization is essential for good quality.

Vicalloys are principally iron, cobalt and vanadium. Vicalloy 1 contains about 9.5% vanadium and does not depend upon cold-working for its properties.

Cunife is a copper-nickel-iron alloy that is malleable, ductile and machinable. Cunife magnets are made from wire stock; this material has directional properties and must be magnetized in the direction in which it was drawn. It is better magnetically in the smaller sizes and only magnets less than 0.25 in. in dia. are made from this material. In small sizes Cunife has a tensile strength of approximately 120,000 p.s.i. and electrical conductivity 9.2 times that of copper.

Cunico 21 is a copper-nickel-iron alloy that is ductile, malleable and machinable. It has a lower residual induction, but a higher coercive force than Cunife and can be produced in a greater variety of forms. Cunico magnets are made from rod, strip, or wire forms. Cunico, unlike Cunife, can be magnetized in any direction.

Comol is a magnetic alloy of cobalt, molybdenum and iron. It has good machining and fabricating qualities and magnetic properties superior to those of chromium, tungsten, or cobalt magnets, and is better adapted to the casting of large magnets of simple contour than to small, intricate shapes. Holes in magnets of this material are usually drilled after heat treatment rather than cored in the casting. When a high flux density is required in a short air gap, Comol serves well.

Vectolite 61 is a nonconducting material made from iron and cobalt oxides. Its outstanding features are: (1) light weight, (a specific gravity about half that of other solid magnet materials); (2) high electrical resistivity; and (3) a coercive force higher than Cunico or any of the Alnicos (except No. 12).

Vectolite magnets are made by mixing powders of cobalt and iron oxides, pressing to shape, and sintering—a process similar to that used for sintered Alnico magnets. Vectolite may be ground, with the proper technique.

Silmanal is a silver-manganese-aluminum alloy with unusual magnetic properties for special applications. It is ductile, malleable and machinable, has a low residual flux, a high coercive force, and a consequent ability to withstand severe demagnetization effects. Silmanal requires a magnetizing force of 20,000 oersted or 40,400 ampere-turns per in. of length, making long pieces difficult to magnetize.

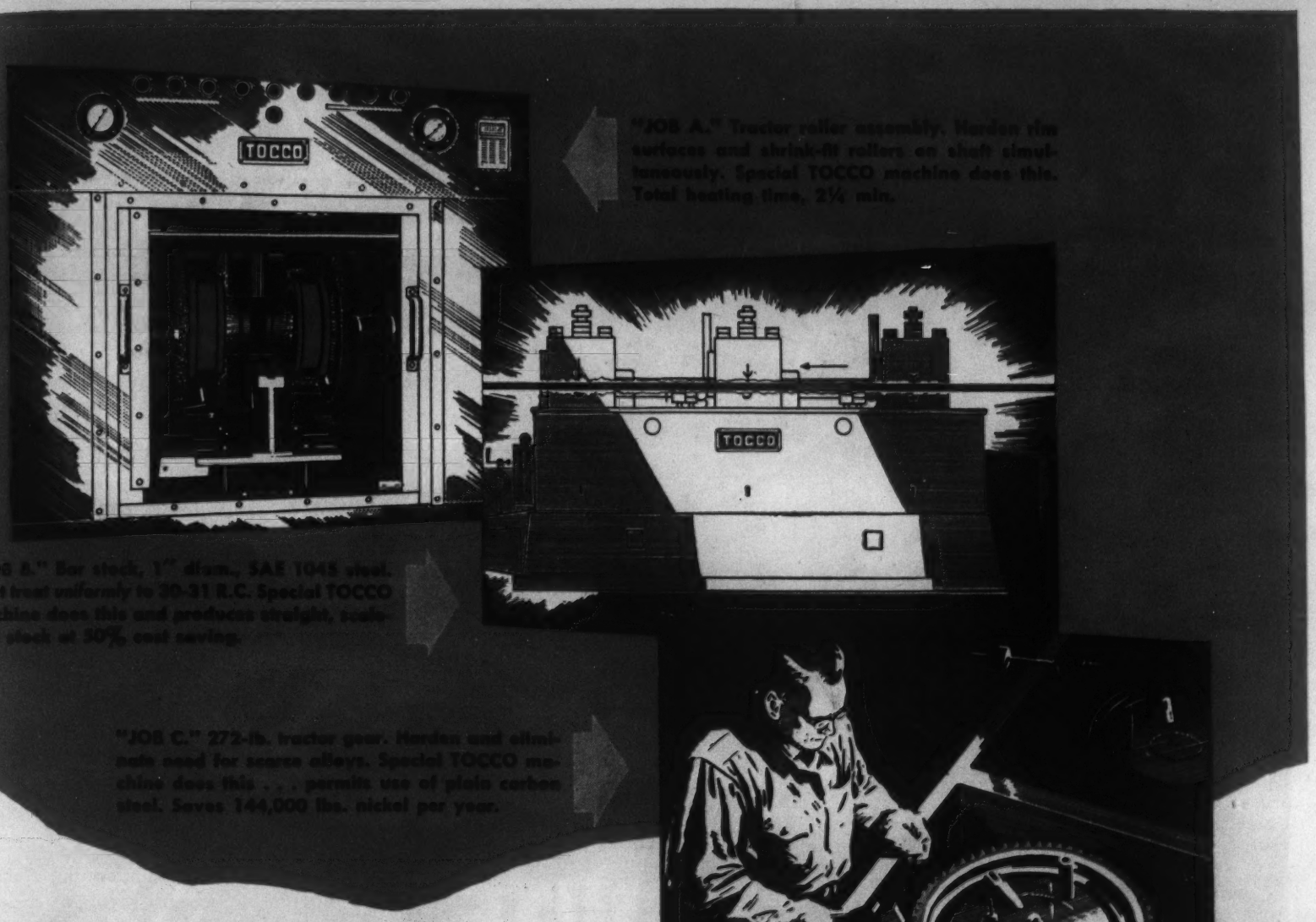
Silmanal is used where magnets are subjected to extreme demagnetizing effects, such as in heavy a.c. fields. In instruments used for measuring the strength of permanent magnets, Silmanal is used as the moving element. (W. E. Ruder. *Iron Age*, Vol. 157, May 9, 1946, pp. 65-69.)

Fracture of Bronzes

Condensed from "Metal Industry"

The examination of the fracture of chill cast bronze gives important information on gas porosity, shrinkage porosity and inclusions. The fracture should cover as large an area as possible, and should include portions of the outside and center. It is desirable to have a series of standard fractures for comparison.

Each bronze has a characteristic fracture color that depends on the color of the alpha solid solution and the compounds present. Poor casting conditions and segre-



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"JOB C." 272-lb. tractor gear. Harden and eliminate need for scarce alloys. Special TOCCO machine does this . . . permits use of plain carbon steel. Saves 144,000 lbs. nickel per year.

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get ABSCO-MEEHANITE castings

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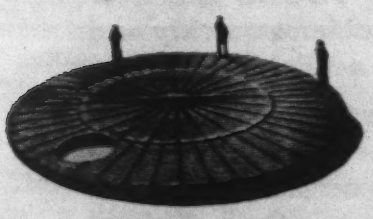

Heat resistance is combined with other Absco-Meehanite properties. A wide range of choice makes possible a close match between the metal and its service. The giant distributor plate assembly shown at the left, for instance, demanded strength, corrosion resistance and machinability to complement its first requisite — resistance to heat. In this unusual application, each of no less than 90 separate castings fits into a place of its own in the completed assembly.

"Unusual castings for unusual service" is more than a catchword at American Brake Shoe Company — it is a watchword for those seeking specification castings on a production basis — castings backed by a knowledge of foundry techniques that is unmatched in the industry. Write and tell us your specific needs.

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1. Strength (Shear, Compressive, Tensile and Transverse)
2. Impact Resistance
3. Corrosion Resistance
4. Wear Resistance
5. Heat Resistance
6. Toughness
7. Rigidity
8. Machinability
9. Pressure Tightness
10. Vibration Absorption

4627

gation will change the color. Small colored patches found in badly cast bronze indicate fissure porosity due to shrinkage or gas, and are accompanied by poor mechanical properties.

Small shiny patches, usually whitish or yellowish, show the presence of nonmetallic inclusions and are nearly always accompanied by colored patches due to fissure porosity. A broad band around the outside indicates ring porosity caused by entrapped gases from the mold dressing or excessive pouring temperatures.

Isolated cavities, in the form of perfect spheres scattered at random over the surface, are caused by entrapped air resulting from too low pouring temperatures or too slow a pouring rate. Large visible cavities are found only in particularly gassy castings.

Examples are given of the correlation of fractures with mechanical properties for several bronzes. (K. Winterton. *Metal Ind.*, Vol. 68, Mar. 22, 1946, pp. 223-226.)

Corrosion Resistance of Some Nickel Alloys

Condensed from "Transactions of the American Society of Mechanical Engineers"

The corrosive attacks on the materials used in cracking and refining processes are explained. The principal corrosion problems are those caused by (1) acids (hydrochloric, sulphuric, hydrofluoric, phosphoric, etc.), (2) bases (sodium and potassium hydroxides, ammonium hydroxide, etc.), and (3) salts (aluminum chloride, boron chloride, etc.). A galvanic series of 43 metals and alloys is given in the order from the corroded end (least noble, anodic) formed by magnesium, to the protected end (most noble, cathodic) formed by 18-8-3 stainless steel type 316 (passive).

Refinery corrosion is discussed in two groups, the dividing line of which is formed by the temperature level at which water is no longer present, assumed at 500 F. Above this temperature, "dry" corrosion is considered to take place due to the action of sulphur and also some organic acids; below this temperature, "wet" or electrolytic corrosion is assumed to take place.

A general survey of refinery corrosion is as follows: At temperatures above 500 F, chromium is the most useful metallic element to resist action of sulphur, the necessary chromium concentration in the metal depends on the sulphur content and the nature of the sulphur compounds. 18 chromium, 8 nickel, 11-14% chromium steels, and 4 to 6% chromium steels are widely used under these conditions.

Where naphthenic acids are a source of corrosion above 500 F, the following alloys are employed: Inconel (about 80 nickel, 13% chromium), and type 316 (about 18 chromium, 14 nickel, 2 to 3% molybdenum). At temperatures below 500 F, corrosion is considered to be electrolytic in character, assuming that liquid water is present to form an electrolyte; it takes place mostly in the condensing and isomerization equipment, alkylation units, caustic regenerators, and in the hydrogenation process.

Condenser shells are of Monel-clad steel, or tubes of 70-30 copper-nickel are used

Meet Black Giant

A New Graphitic Oil-Hardening Tool Steel

- It machines beautifully.
- Its self-lubricating qualities mean lower friction—longer life in many kinds of tools.
- Oil-hardening, it responds readily to heat-treatment—and hardens deeper than most graphitic steels.
- It has excellent non-deforming properties.

Use it for deep-drawing dies; bushings, mandrels, seaming rolls; bending and stamping dies; plug or ring gages; and a host of other tools requiring high resistance to wear and abrasion.

Black Giant does not replace BTR, Bethlehem's oil-hardening tool steel. Rather, it complements BTR in many special applications like those listed above.

TYPICAL ANALYSIS

C	Mn	Si	Cr	W
1.40	0.90	2.20	0.45	0.30

BETHLEHEM STEEL

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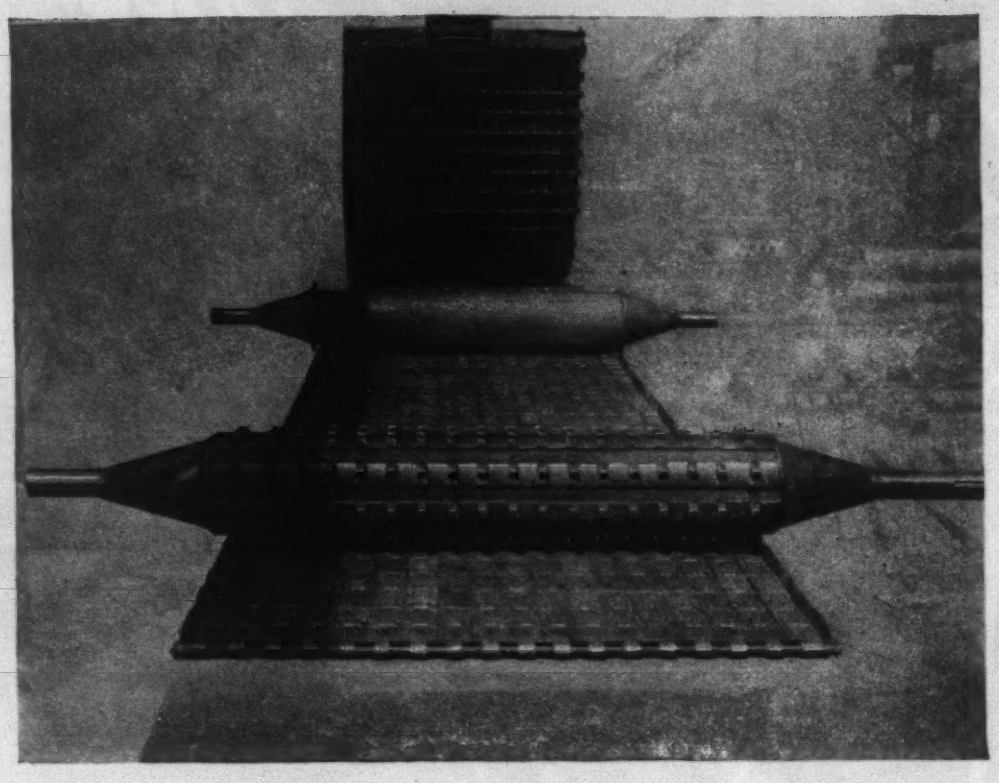

It's a conveyor assembly for a heat-treating furnace, alloyed and cast for a large manufacturer of automobile parts. Perhaps you would be interested in some facts:

Alloying Elements . . 15% Chromium, 35% Nickel
Conveyor Belt . . . . 8,400 pounds, statically cast
Head Shaft . . . . . 1,625 pounds, centrifugally cast
Tail Shaft . . . . . 804 pounds, centrifugally cast

The belt consists of several thousand individual links assembled and held together by alloy steel rods. No machining of the links was necessary. The lugs on the head shaft were cast integrally with the shaft. The end cones on both shafts were cast statically and then welded on.

You may not need a conveyor for a heat-treating furnace such as this, but if you need any high alloy casting—for resisting heat, corrosion or abrasion—we would like to discuss producing it for you. Our experience in static castings goes back to 1922 and in centrifugal castings back to 1931, both pioneering dates.

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that offer greater resistance to impingement attack than Admiralty tubing. For isomerization equipment, Hastelloy B, an alloy of approximately 60 nickel, 32% molybdenum is one of the most resistant to an hydrochloric acid atmosphere. Monel seems to be the most useful material in aklylation, using hydrofluoric acid as catalyst; it is used as liners for vessels, valves, rings and packing. The same metal is used also to line caustic regenerators.

Ni-resist cast iron (nickel or nickel-copper cast iron) of austenitic structure is useful for pumps and valve parts in handling caustic. 18:8 stainless steel is highly resistant to hydrogen attack although it suffers some temporary loss in mechanical properties due to mechanical presence of hydrogen in the metal; the hydrogen can be removed by heating, and its properties restored.

For other steels, presence of carbide-forming elements (chromium, tungsten or molybdenum) are required to prevent decarburization. In general, the more complex the carbide the more resistant is the metal to decarburization under hydrogenation conditions. Unless 12% or more of chromium is present in the steel, sulphur attack must be expected. (B. B. Morton. *Trans. Am. Soc. Mech. Engrs.*, Vol. 68, Apr. 1946, pp. 229-235.)

Alloy and Tool Steels in India During World War II

Condensed from a Paper Presented Before the 33rd Indian Science Congress

Ferrous metallurgy has created a new field in the manufacture and utilization of alloy steels. Under the stress of war, great strides have been made in the metallurgy and in the development of alloy steels that are free-machining, corrosion-resistant and heat-resistant. In the early years of the Indian steel industry, the early 30's, high tensile steels were developed in order to employ higher fiber stresses in structural design.

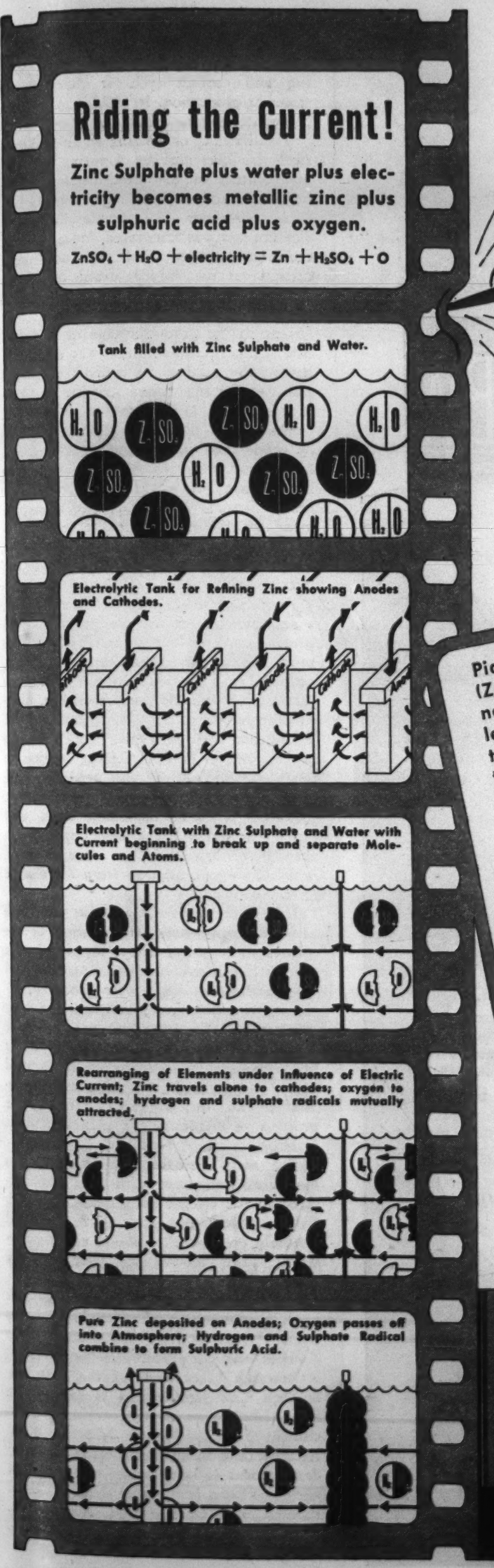
Two steels were developed in the pioneering days by the Tata Iron & Steel Co. The first alloy high tensile structural steel came into being as "Tiscom" steel was developed for construction specifications of the Howrah Bridge, Calcutta. It was a high tensile structural steel having a tensile strength of between 83,000 and 97,000 psi. This, a quarternary steel with alloy additions of chromium, manganese and copper, can be safely welded only if preheated. Therefore, "Tiscor", a quinary steel containing alloy additions of chromium, copper, silicon, and phosphorous—a structural steel having a high yield strength yet lending itself to welding in the usual way—was developed. In addition to having a high yield strength, "Tiscor" is more corrosion resistant than plain carbon structural steel.

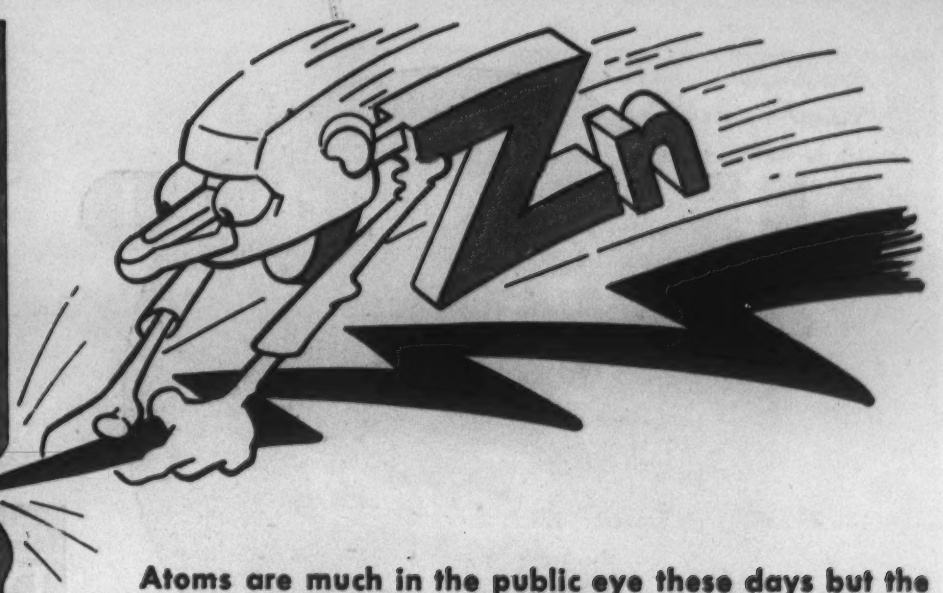
Bullet-proof armor plates were demanded by the government and, influenced by existing available plant and equipment, alloy steel of the air-hardened type was developed in about three months. It was a basic open hearth steel and contained nickel, chromium and molybdenum. The ballistic test requirements were met by a simple normalizing treatment followed by tempering at a low temperature.

Riding the Current!

Zinc Sulphate plus water plus electricity becomes metallic zinc plus sulphuric acid plus oxygen.

$ZnSO_4 + H_2O + \text{electricity} = Zn + H_2SO_4 + O$





Atoms are much in the public eye these days but the importance of atomic activity is not entirely confined to a devastating reaction chain. Other atoms, likewise unseen and unseeable, are playing a leading role in one of the most important of industrial processes—*the electrolytic purification of zinc.*

Picture if you will a tank filled with a zinc sulphate ($Zn^{++}SO_4^{--}$) and water solution. Suspended alternately in this solution are anodes and cathodes, the lead silver anodes or positive pole being connected to a source of direct current. Cathodes, on the negative side, are sheets of aluminum. In a zinc sulphate solution, the zinc atom stays tied to the sulphur and oxygen atoms. Turn on the current lever and a strange thing happens—several strange things. The zinc atom drops the sulphate, climbs aboard the current as it leaves the anodes and rides to the cathodes. There, it hops off and builds up a cake of very pure zinc. The water ($2H^+O^{--}$) also breaks up, the hydrogen combining with the sulphate (SO_4^{--}) to form sulphuric acid (H_2SO_4) which is periodically removed for use elsewhere in the process. The oxygen in the water (O^{--}) is attracted to the anode where it passes off into the air.

One phenomenon connected with the electrolytic purification of zinc is that practically all impurities in the sulphate solution stay behind. The zinc deposited is consistently 99.99+ % pure—zinc such as Bunker Hill.

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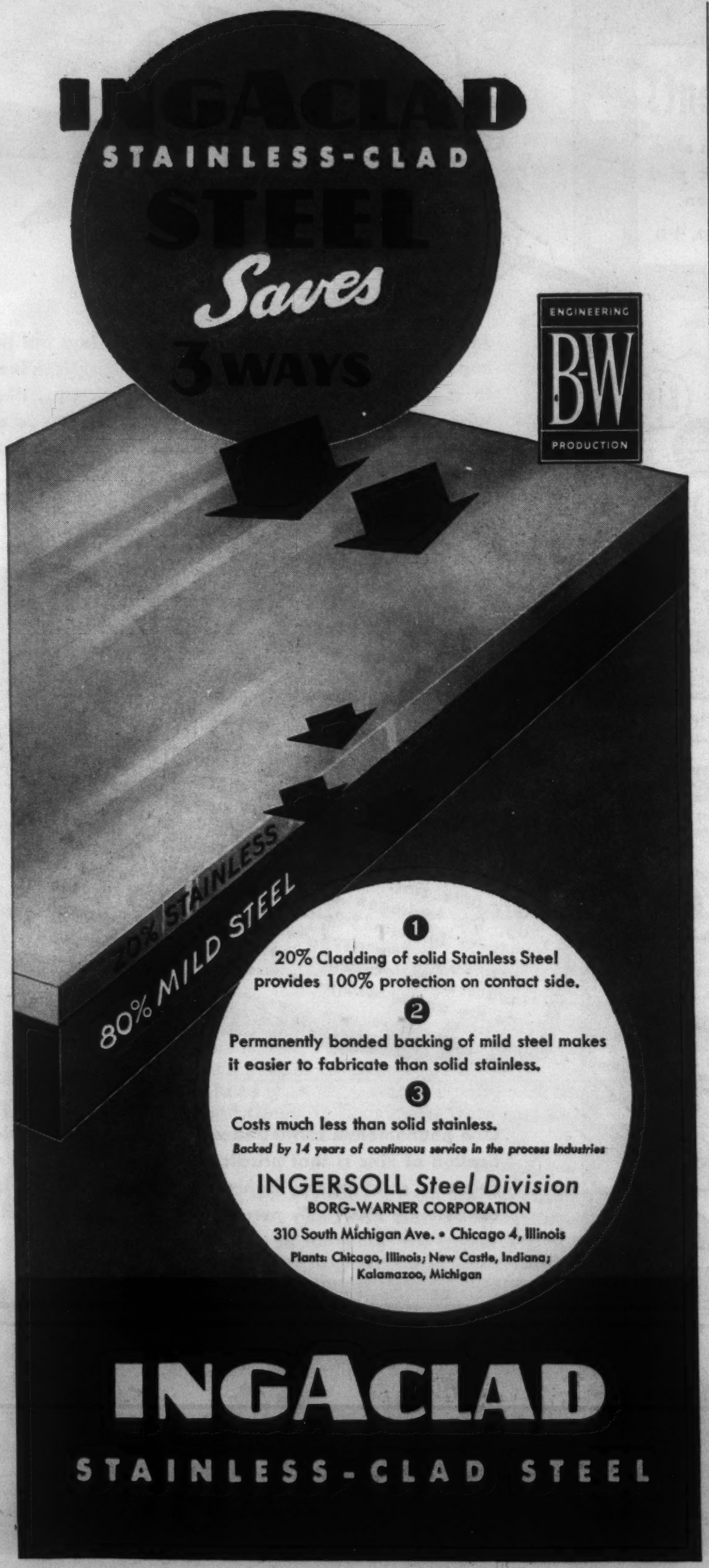

The extreme sensitivity of this steel to heating and cooling and the tendency for "flaking" was cured by a controlled heating and cooling cycle at the different stages of production. Its welded joints were proven to be much stronger than riveted.

The difficulty of welding an air-hardened steel was overcome by lowering the carbon content of the steel, decreasing the brittleness and yet not impairing its ballistic properties. A suitable flux-coated welding rod was discovered and a welding technique evolved that did not cause cracking at the welded joints; these rods were far better than many foreign-made rods.

Due to the acute shortage of nickel, a new composition of armor was developed having the same good ballistic properties and welding steel characteristics, but having less than 1/3 of the original nickel content. Most of the nickel was replaced by copper and silicon, and chromium and manganese were increased. The Indian armor plate possesses the advantage of a greater latitude in the range of heat-treatment, which remains constant for all sectional variations, thus allowing for a standard heat-treatment range for varying thicknesses.

As sources of haematic iron were cut off, a new method for the production of acid steel was worked out at Jamshedpur. This procedure employed an all-scrap charge, carbon being included in the charge as petroleum coke. Alloy steel shell bar, high-sulphur free-machining steels, forgings for armaments and alloy bar stock for the production of armor piercing projectiles were also successfully produced, as were later demands for various special steels. Synthetic pig iron was made from steel scrap and carbon in a basic open-hearth furnace which was much cheaper than, but still as good as, iron from the electric arc furnace.

During the war there was also a shortage of small coins. After examination of the imported steel a satisfactory supply of mint die steel was manufactured. Also, several types of magnet steels were produced, including the chromium, tungsten and high cobalt types. The successful production of high-silicon steel sheets, brought about by demands for nonimported steels used in the manufacture of electric motors, dynamos and transformers, indicates the prospect of establishing a stamping works in India.

The many demands for miscellaneous tool steels were met with steel manufactured in the electric arc furnace, the high frequency induction melting furnace and similarly processed. Corrosion and heat resisting steels for various purposes have been successfully produced.

The important tungsten high-speed steels used in ammunition were produced, being reduced from wolfram ore obtained from Jodhpur and elsewhere. The New Control & Research Laboratories of the Tata Iron & Steel Co., Jamshedpur, is one of the finest laboratories in the world. The facilities afforded by these laboratories for research have made possible the successful development of manufacture and supply of alloy steels and many other steels of special strategic importance. (P. H. Kutar. *Proc., 33rd Indian Science Congress, Bangalore, 1946.)*

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Write for your copy of this new Bulletin No. 68A describing the complete line of Ampcoloy Resistance Welding Alloys and Electrodes.

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. . . a complete line of finer quality, from one dependable source

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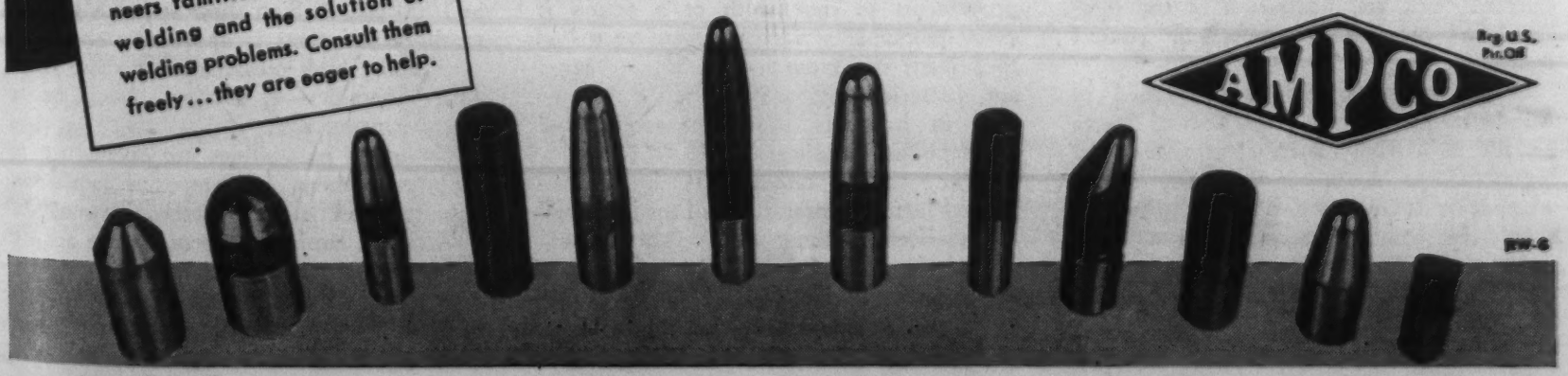


NONMETALLIC MATERIALS

Design-uses of plastics, plywood, fibre, glass, rubber, ceramics, etc. as engineering materials. Composite metal-nonmetal combinations. New forms of nonmetallic materials.

Wood Treatments

Condensed from "Mechanical Engineering"

Progress in wood finishing will be evident in both the physical improvement of film structures and in economic values gained from better methods of application. Chief considerations will be: Mar resistance, chemical resistance, improved clarity and depth, improved preservation of the wood, and longer film life and durability.

As to economic improvements, the following possibilities are evident: lower costs per unit volume of finishing material which may be applied, due to higher solids concentration; savings in time, labor, and storage space due to improved drying schedules, savings in time and labor through the elimination of multiple-coat finishes, and savings from the use of new types of equipment and methods of application.

The following basic types of raw material have been investigated: melamine finishes, melamine-urea-formaldehyde finishes, vinyl coatings, styrene coatings, acrylic coatings, polyamide finishes, improvements in previous systems such as phenolics, alkyds, etc., the use of varying viscosities and newer-type cellulose esters, *e.g.*, acetate, butyrate, etc., and utilization of the new-type, low-pressure laminates, or contact resins.

Much experience has been gained in wood treatment by the Army Service Forces for use in a wide variety of climates. The Signal Corps advocates that any wood, whether it is untreated wood or plywood, should be basically treated with a wood sealer of the Class 638, in accordance with the Army Ordnance Specification T.A.C. E.S. -680.

It is required that this treatment material be a solution that is pigment-free and contains 16% water-repellent solids at time of application. Type 1 is required to dry in 1 hr. and contains alkyds only; type 2 is required to dry in 18 hr. and contains treated oils free of rosin and rosin derivatives. The various fungicidal ingredients are as follows: 0.02% based upon weight of solids of phenyl mercuric oleate, or 5% based upon weights of solids of chlorinated phenols consisting of pentachloro phenol between 80% and 100%, chloro-ortho-phenol, 0 to 40%, and tetra chloro phenol, 0 to 30%.

Other methods okayed by the Signal Corps to protect against drastic elements are: using impregnating salts under pressure as a substitute for the wood sealer; using a creosote blend as an impregnant on wood as a preservative, and using a hot-oil blend with 15% pentachloro-phenol at 160 F as an impregnant on wood, with an immediate cold-oil immersion application.

As to protection against fungi and bacteria, one can visualize the possible improvements to the health of a nation if every paintable surface were so treated as to prevent the growth of infectious fungi and bacteria. Such treated woods may be used in hospitals, schools, theaters, and other public buildings.

While much remains to be accomplished in the laboratory, the broad outlines of knowledge have been attained and proved. The chief hurdle is complacency with past performances. (H. E. Smith. *Mechanical Engineering*, Vol. 68, May 1946, pp. 425, 426.)

Cementing Phenolic Laminates

Condensed from "Plastics"

Laminated phenolic plastics have been introduced to numerous assemblies where high strength, good mechanical durability, and good dielectric properties are paramount. They have superior electrical and mechanical characteristics. However, such parts are usually assembled with mechanical screws, rivets, springs or dovetailed devices, and provision for such fasteners usually entail redesigning from the original.

But now furane resin adhesives have been devised which make possible unusually strong and reliable cemented assemblies, fully as strong as the original materials being bonded. A complete mechanical and chemical bond is provided.

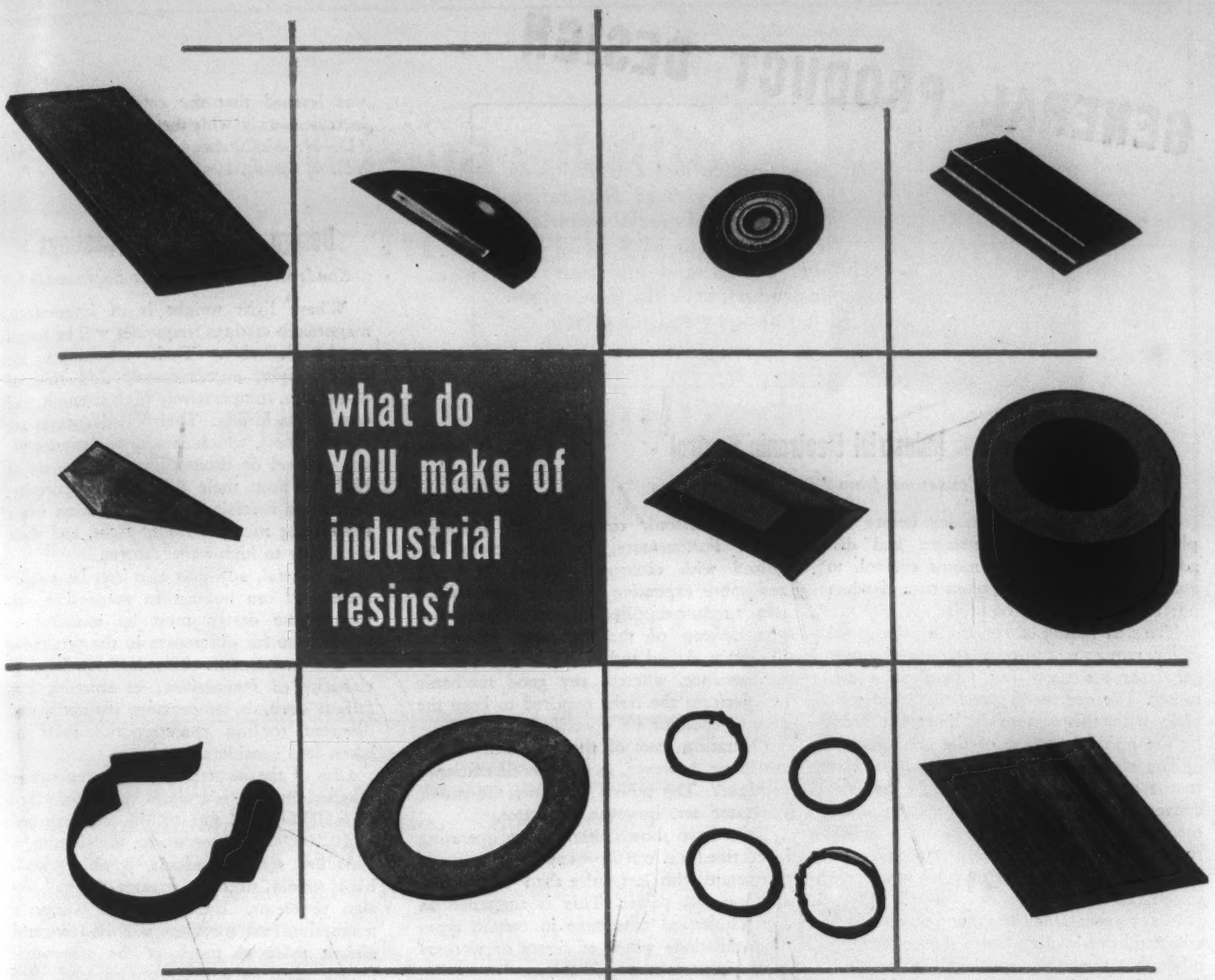
A striking example is the assembly of a spool from canvas-base laminated phenolic. Previously, the complete spool was wastefully machined from a large block of laminate, or else a small diameter rod was machined and threaded for assembly to the end flanges. Both were reliable except for the creep in the threaded attachment.

The cost was much reduced when it became possible to assemble sheet stock and the rod about a mandrel, with the aid of furane resin cement. The new adhesive has exploded an old theory that when two surfaces are to be joined it is best to roughen the surfaces to provide more surface area and mechanical interlocking. With furane resin best bonding occurs with a smoothly polished surface without mechanical roughening. This would indicate a true chemical bond.

There are a few design rules to be recommended in the bonding of laminated thin sheet stock (⅛-in. thickness and under). A few tack rivets should be used at the edge to prevent the sheets from starting to unpeel because of some unusual mechanical action; an additional reinforcing strip at the edges to increase the overall thickness will prevent any incipient fold-back, and the high shear strengths of the glue will be utilized; there is considerable improvement when the edges are scalloped or finished in a toothed design, as would be obtained with pinking shears.

Discussion so far has involved canvas-base laminates. Material failures occurred in polyester resin laminates at 3,000-3,500 psi.; in Grade XX paper-base phenolics, 1500-2000 psi. and in Masonite die stock at 1000 psi. A high shear strength parallel to the laminations is apparently characteristic of the high pressure canvas-base laminates phenolics—a strength much better than for paper base.

Unlimited possibilities are opened up in the development of composite laminates. Unusual and attractive combinations of acrylics and laminated phenolics are among their number. Custom laminating of dissimilar components should have great sales appeal. (John Delmonte. *Plastics*, Apr. 1946, pp. 62, 64, 66, 92, 93.)



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GENERAL PRODUCT DESIGN

Selection, applications and design of parts made by various fabricating methods or made of special materials. Properties and uses of finishes and coatings. Design and materials for specific products or fields. General engineering design trends or principles.

Industrial Electronic Control

Condensed from "Product Engineering"

This article attempts to lay before the plant engineer the advantages and disadvantages of electronic motor control, to assist them in deciding when to and when not to use electronic control.

The first means of controlling the speed of a.c. motors was through the use of motor generator set supplying power to a d.c. motor. The degree of speed reduction possible with this system is limited usually by the residual voltage of the generator.

The electronic control system is similar to the motor generator set except that the conversion of a.c. to d.c. is accomplished through a rectifier tube. Separate rectifiers supply field and armature circuits; the voltage of both circuits may be separately varied for maximum speed control.

Motor generator sets are sturdy and withstand overloading better than electronic tubes, but they have considerable lag, and do not have the almost instantaneous speed of response of vacuum tubes. A great variety of circuits, too, may be applied to change the motor characteristics by remote control. These factors frequently permit increased production through the installation of the electronic system of control.

When compared to a motor generator set with necessary control, the first cost of an electronic control is 15 to 50% more. Furthermore, the d.c. motor required with electronic control is larger and more expensive than the same horsepower motor supplied by a motor generator set. Upkeep of the electronic system is higher; a skilled technician is required for maintenance, whereas any good mechanic can perform the tasks required to keep the motor generator set operating.

Operating costs of the electronic system are lower, however, as the overall efficiency is higher. The power factor of the motor generator set, however, is better.

Tests have shown that motors operating by rectified a.c. can in many cases be made to operate with less noise than when operated on d.c. power. This is suggested as a psychological advantage in certain types of installations where efficiency of workers is an important consideration.

The lack of an extensive published literature on the subject of electronic motor control is not due to a small volume of research, but rather to the reluctance on the part of many to publish industrial information which is made obsolete so rapidly by the rapid strides being taken in the field. (S. S. Wolff. *Prod. Engineering,* Vol. 17, May, 1946, pp. 353-357.)

X-Ray Stress Analysis

Condensed from "Industrial Radiography"

The application of X-ray diffraction methods to the solution of industrial problems is increasing and, with the newer uses of electrical devices for recording the diffraction effects, their use will be more common as the techniques are refined. To both the designer and the experimental engineer, the methods of stress analysis are of great importance.

As an example of the use of an X-ray technique, the following is cited. After the change from individually drilled to gang-punched rivet holes in the Dural (24 ST) sheets employed in aircraft construction, serious splitting of these sheets starting at the punched holes began to appear in service. After focusing a narrow beam of X-rays on the sheet near the edge of one of the punched holes, it was learned that severely deformed and strained grains existed in the Dural up to about 0.005 in. out from the hole. To remedy this, it was necessary to ream at least 0.005 in. of stock from around the punched hole.

Quantitative examination of stresses in metallic materials is possible using a microphotometer to measure and interpret the resulting diffraction pattern. With its use an accuracy of plus or minus 8000 psi. is possible with samples of heat treated steels; even greater accuracy is possible (within 2000 psi.) in the case of annealed steel.

X-ray diffraction techniques have also been applied to the examination of shot-peened steel parts where it was desired to gage the magnitude and depth of the compressive stresses produced by the peening. Sub-surface stresses, however, can not be checked with any accuracy by this method. Through studies of this type, it was learned that the compressive stresses increase slowly with the shot-peening time. (D. N. McCutcheon. *Ind. Radiography,* Vol. 4, Spring 1946, pp. 9-16.)

Design of Magnesium Castings

Condensed from "Product Engineering"

Where light weight is of importance, magnesium castings frequently will be found to be desirable. Their advantages are light weight, approximately 2/3 that of aluminum, comparatively high strength, and ease of machining. Their disadvantages are their softness, which usually necessitates the use of steel or bronze inserts at points of high loading, their tendency to porosity, frequently necessitating impregnation when the casting must be liquid tight, and their sensitivity to high temperatures.

In general, any part that can be cast in aluminum can be cast in magnesium, although the design must be modified to compensate for differences in the properties of the two metals. The low modulus of elasticity of magnesium, its softness, low fatigue strength, temperature sensitivity and different cooling characteristics must be taken into consideration.

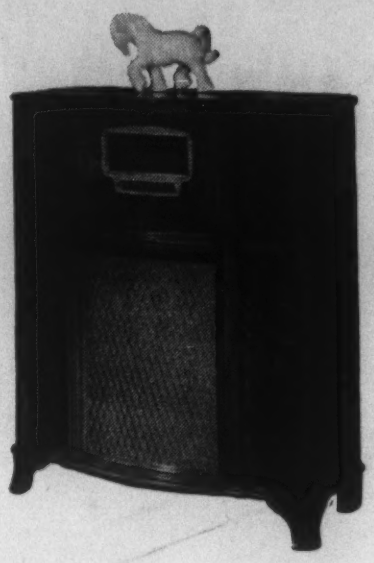
One of the outstanding characteristics of magnesium is its low elastic modulus, which is 6,500,000 lb. per sq. in. as compared to 10,500,000 lb. per sq. in. for aluminum. This low elastic modulus, combined with high tensile strength, creates unusual design problems. Under straight tension a magnesium test specimen will be elongated almost twice as much at the same unit tensile stress as will aluminum, and more than four times as much as steel.

In addition to the low elastic modulus, special consideration must be given to the low shock resistance of magnesium as compared with aluminum. These two factors require that castings be designed with large fillet radii, about twice those that would be used for iron castings, and with generous tapers from heavier to lighter sections.

When magnesium solidifies and cools to 500 F, it is still extremely plastic and retains that plasticity to a considerable degree down to a temperature of 200 to 300 F. As a result the metal exerts little pressure upon cores and is prevented from contracting, so that it conforms to the mold dimensions by plastic flow.

The two magnesium alloys that are most widely used for castings are Dow C or AM 260 and Dow H or AM 265, designated as AZ92 and AZ63, respectively, in ASTM Specification B80-44T. The AZ92 alloy requires careful heat-treatment and is a little harder to cast in intricate sections than is AZ63 alloy. Heat-treatment for AZ92 or Dow C alloy, as recommended by Dow Chemical Co., is 20 hr. at 765 to 775 F, quench in air and then age at 350 F plus or minus 10 F for 16 hr. For its corresponding alloy AM 260, American Magnesium Corp. recommends a shorter heat-treatment of 16 hr. at 780 F, with the same quench and aging that Dow recommends. (C. J. McDowall. *Product Engineering,* Vol. 17, Apr. 1946, pp. 340-343.)

This handsome Radio goes to market...



and this metallized trimmer cuts cost!

THAT, in a nutshell, is the story of component parts made of Corning Metallized glass. In this case it's a trimmer capacitor as used in Stromberg-Carlson's beautiful new "Imperial" radio. It eliminates other parts and speeds up assembly.

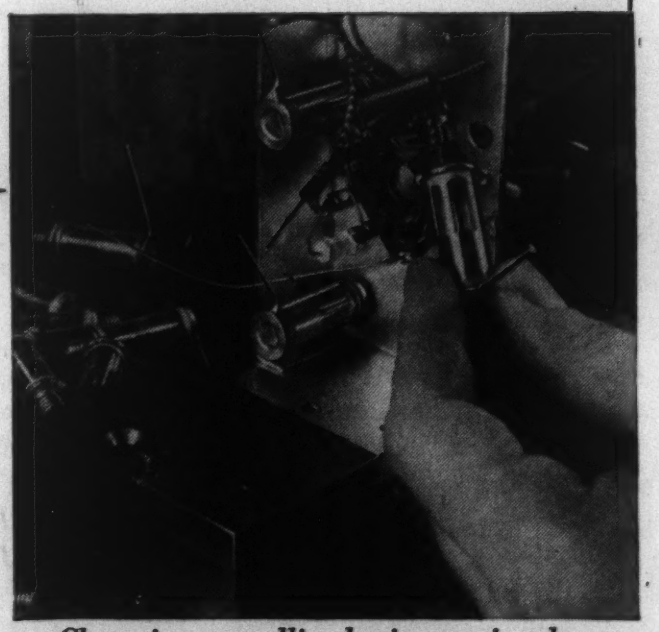
Some other advantages are that it permits permanent, precise and undistorted tuning even under vibration and in high frequency FM bands. Adjustment is made at the electrically cold end of the trimmer. It has a high Q.

It is another example of Corning metallized glass that permits glass parts to be soldered to hardware, permanently, quickly and, where necessary, to form hermetic seals.

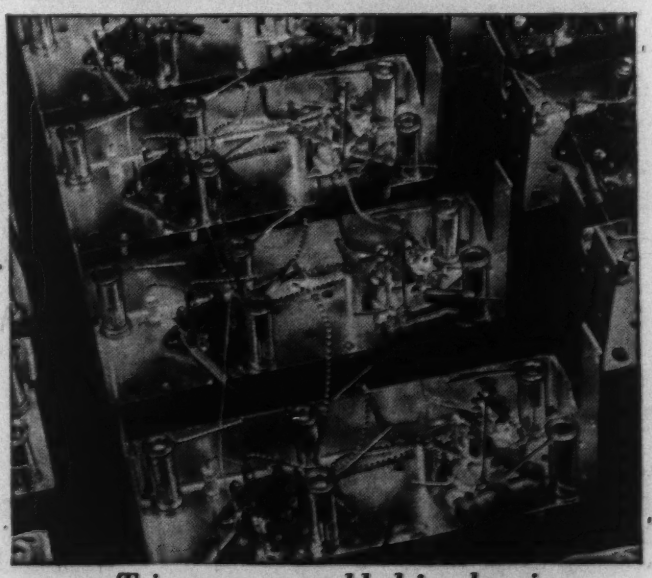
For more information about metallized trimmer capacitors write for Bulletins EI-B-1 and B-2. For the complete story on Corning Metallized Glass Components, write for Bulletin EL-Z-Z-10.

Electronic Sales Department, T-8
Corning Glass Works
Corning, New York

Sales offices in New York, Chicago and San Francisco



Clamping metallized trimmer in place



Trimmers assembled in chassis

CORNING *means* Research in Glass

Electronic Glassware

VYCOR PYREX CORNING — Reg. U.S. Pat. Off.

"PYREX", "VYCOR" *and* "CORNING" *are registered trade-marks and indicate manufacture by Corning Glass Works, Corning, N. Y.*

MELTING and CASTING

Melting, alloying, refining and casting methods, furnaces and machines. Iron and steel making, nonferrous metal production, foundry practice and equipment. Die casting, permanent mold casting, precision casting, etc. Refractories, control equipment and accessories for melting furnaces.

Light Alloy Founding

Condensed from "The Foundry Trade Journal"

Light alloys may be divided into two main groups: aluminum and its alloys; and magnesium and its alloys. For the grain refinement of aluminum castings, titanium or columbium may be added to the metal in the form of an intermediate alloy. The metal is then well stirred and skimmed. Only a very small quantity of grain-refiner is needed. Boron, in the form of salt cakes, is also an excellent grain-refiner and very convenient for treating small quantities of metal.

The cakes are held well in the molten metal until all reaction has ceased. The surface of the bath is then skimmed before casting. When the aluminum contains about 10% magnesium, a specially prepared molding sand is necessary, and a small proportion of bentonite is added.

The cause of "pin-holing" in aluminum castings is the presence of hydrogen in the molten metal. The moisture or other hydrogen compound is reduced chemically by the metallic aluminum, and the hydrogen evolved is absorbed by the molten metal. That is one of the reasons why aluminum should not be kept molten at a high temperature because, as with other metal, its power to dissolve gas increases with increasing temperature.

Before casting, the molten metal may be de-gassed by means of chlorine, nitrogen, or by proprietary products on the market for this purpose. Magnesium melting is carried out in soft steel welded or pressed pots up to 500-lb. capacity, because the amount of iron picked up by molten magnesium is very small.

Furnaces are gas-fired, and are also so designed that the outside of the iron pot is very uniformly heated all over its outer surface. During melting down, the metal is kept covered by a protective flux, consisting of the chlorides, fluorides and oxides of magnesium, potassium, calcium and sodium.

Fluxes, depending on the proportion of the constituents, may not only act as a protective agent by preventing any local burning or fire in the furnace charge, but may also act as refining fluxes for the molten metal.

During casting, the stream of molten magnesium alloy issuing from the ladle is protected from burning by keeping it dusted with powdered sulphur. The molten metal shows less tendency to burn if a small addition of calcium is added to it.

In order to refine the grain of the castings, the molten alloy is subjected to a superheating process. This process consists in heating the metal up to 1562 to 1652 F (850 to 900 C) for a period up to an hr. However, only a short time at the maximum temperature may suffice, but it is important that the molten metal should be brought slowly up to that temperature, and cooling down afterwards must be conveniently quick.

The grain refinement produced by superheating is attributed to the production of very small nuclei distributed throughout the melt. Refining with salts is carried out at much lower temperature than "superheating", the range being 1292 to 1472 F (700 to 800 C). A refining flux of the chemical composition referred to is placed on the surface of the molten metal, allowed to fuse and then worked intimately into the bath. The flux combines with the oxides and impurities, and sinks down with them to the bottom of the pot, owing to its greater weight, leaving the metal clear and bright. (E. W. Fell. *Foundry Trade J.*, Vol. 78, Mar. 1946, pp. 335-339.)

Structural Changes vs. Deoxidation

Condensed from a Paper of the American Society for Testing Materials

Annealed and normalized samples of carbon and molybdenum steels were examined for changes in hardness and microstructure after exposure at 900, 1000 and 1100 F for periods up to 5000 hr. The SAE 1015 steels were deoxidized in the ladle with 10 lb. ferro-silicon per ton and differing amounts of ferro-carbo-titanium, and in the mold by differing amounts of aluminum. The molybdenum steels contained 0.1 to 0.2% carbon and 0.5% molybdenum.

Four of these steels were from heats with low and high ferro-silicon additions in the ladle, with and without aluminum additions in the mold. The fifth had been deoxidized with ferro-silicon-zirconium in the ladle and had no addition in the mold. The sixth had no ladle addition but a very high aluminum addition in the mold.

The hardness of most of the carbon steel samples and of the annealed molybdenum steels first increased slightly with time at temperature, then decreased slowly at about the same rate at each of the three temperatures. The changes appeared to be uninfluenced by the deoxidation practices used.

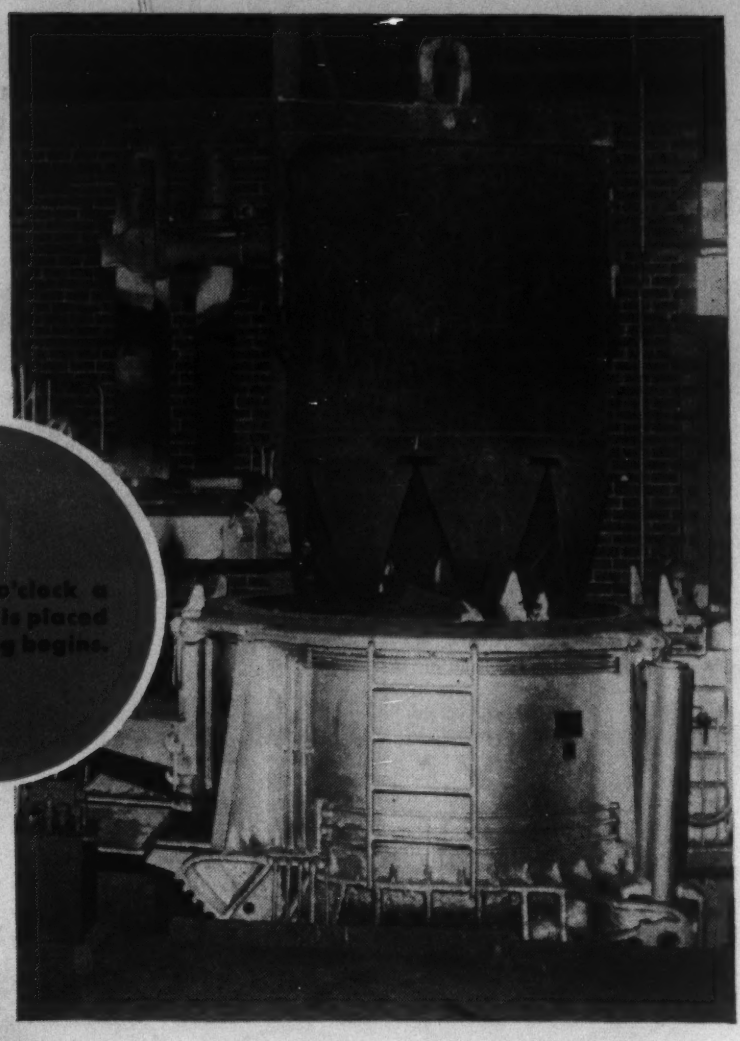
The rate of spheroidization of the normalized steel was generally greater than for the annealed steels, but the effect was less marked in the carbon steels. In the normalized carbon steels, this rate was highest in the high titanium treated steel. In the molybdenum steels the rate increased with increasing silicon plus aluminum addition, whereas a large aluminum addition without silicon was associated with a lower rate.

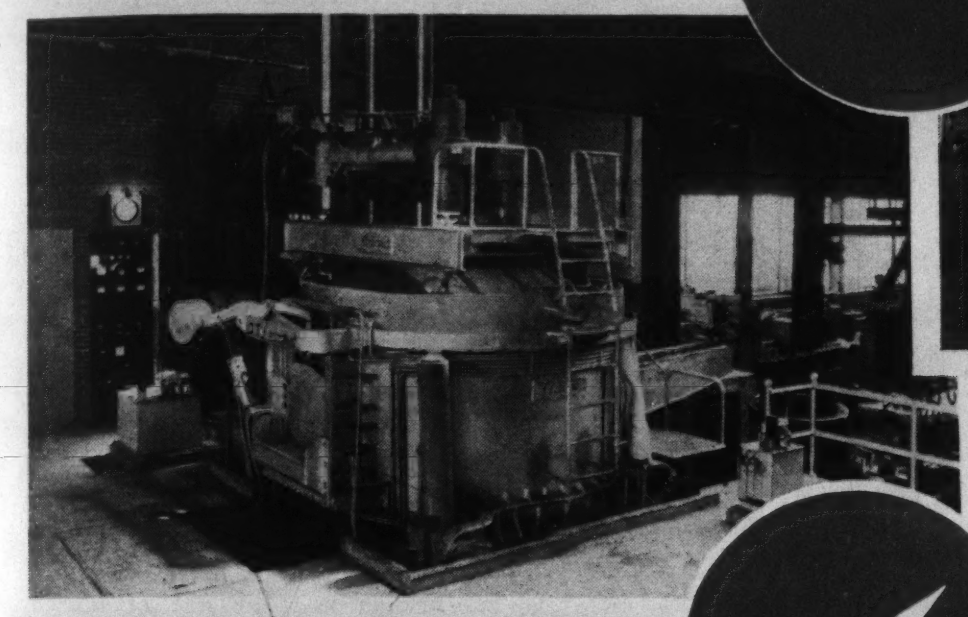
Graphite formed in all the carbon steels at about the same rate in both normalized and annealed specimens. In the six molybdenum steels, it formed only in the three to which aluminum had been added; in these the rate seemed to be faster the higher the silicon content and faster in the annealed than in the normalized samples, only one of which showed graphite. In both groups, graphitization was generally faster the higher the temperature within the range studied.

The fact that spheroidization is apparently accelerated by aluminum addition and that (in the molybdenum steels) graphitization occurred only in steels to which aluminum had been added indicates some sort of relationship. This does not mean, however, that spheroidization must precede graphitization. Perhaps aluminum additions serve to increase the diffusivity of carbon and thus spheroidization and graphitization, while the alumina particles resulting from deoxidation aid somehow in nucleating graphite. (G. V. Smith, R. F. Miller & C. O. Tarr. *A.S.T.M.* Preprint No. 19a, 1945.)

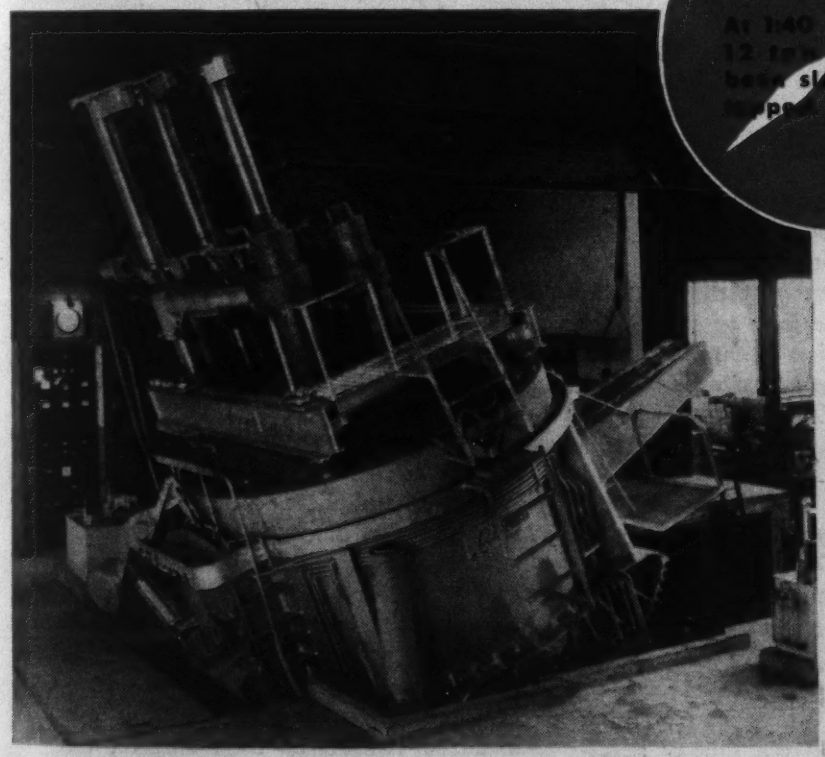
12 TONS - 100 MINUTES

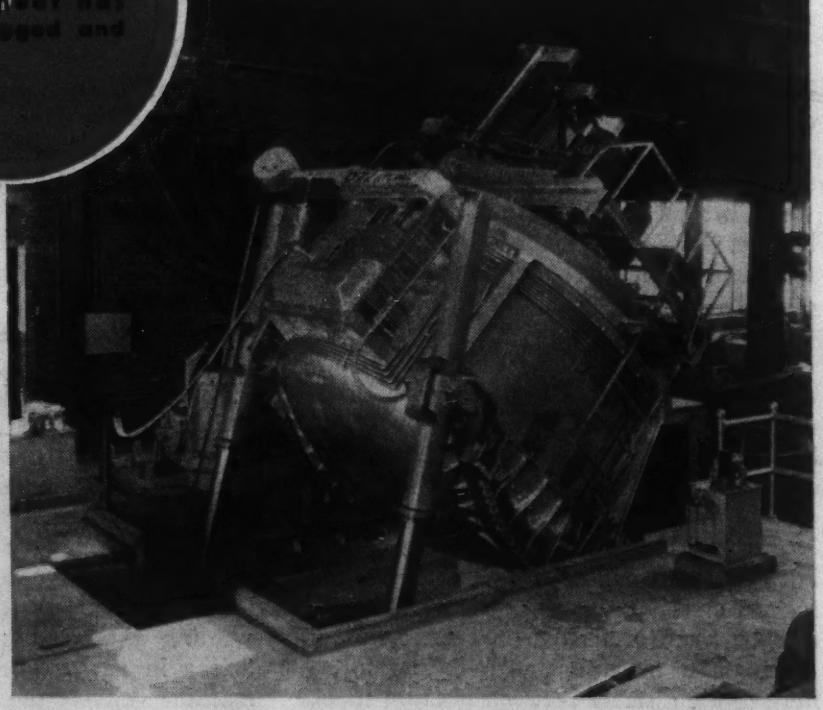
THAT'S *Clockwork* *Economy* IN METAL MELTING





This furnace is size OT (usual heat size 10 to 12 tons). Other equally fast and economical Lectromelt top charge furnaces are available in capacities ranging from 100 tons down to 250 pounds.





MOORE RAPID *Lectromelt* FURNACES

PITTSBURGH LECTROMELT FURNACE CORPORATION

PITTSBURGH 30, PA.

FABRICATION and TREATMENT

Machining, forging, forming, heat treating and heating, welding and joining, cleaning and finishing of solid materials. Methods, equipment, auxiliaries and control instruments for processing metals and nonmetals and for product fabrication.

Spot Welding Light Metals

Condensed from "The Engineers' Digest"

There are limitations to the application of spot welding in aircraft manufacture, viz: (1) Parts exposed to heavy and changing loads are usually riveted; (2) parts which are to be interchanged may need to be riveted; (3) parts which are inaccessible for welding must be riveted; and (4) quantity must be sufficient to justify the purchase of the tools and electrodes.

The impression of the electrode on one or both of the surfaces of the work is the only characteristic of spot welding that can be seen and measured without difficulty. Its diameter increases in proportion to the thickness of the sheets. In general, the largest impressions may be considered best, but above certain sizes cracks occur on the surface and heat damaged surfaces appear that are more or less exposed to corrosion.

Although there is practically no lower limit to the distance between welding spots, the closer the spots the greater the waste of current. The spot strength increases with the distance, whereas the seam strength is the greater the nearer the spots are to each other.

Considerations of strength require small distances between welding spots, while shop practice and economy ask for large distances. The final decision depends always on the purpose and stresses in the weld, but as a general guide it can be said that distances of spots between 12 mm. (0.472 in.) and 25 mm. (0.984 in.) should be used according to the thickness of the sheets.

The external impression does not always allow correct conclusions to be made as to size and structure of the spot weld. This is only possible by destroying the specimen either by separating the joint or cutting the specimen in two. It has been determined that the diameter of the actual welding spot must be not less than 90% of the diameter of the impression in order to assure a satisfactory joint.

In contrast to these methods, the X-ray test allows examination without destruction of the weld. Although the use of X-ray for testing spot welds has only just been started, its great advantages are already recognized.

A system of direct control during the welding process has been developed by Sciaky in Paris. The Sciaky spot welding machine delivers the electric energy necessary for obtaining a spot weld in one impulse. Since the size and structure of the spot weld is influenced mainly by the current, control of this current means controlling the spot weld. The increased expenditure of time and labor connected with the introduction of the Sciaky machine with its control apparatus is negligible compared with the advantage of improved quality of the welds. (W. Heiz. *Engineers' Digest* (British), Vol. 7, March 1946, pp. 60-63.)

Flame Hardening Cast Iron

Condensed from "The Foundry"

Flame hardening can be defined in a general way as the process of heating the surface of a ferrous material above its critical temperature with an oxyacetylene flame and rapidly cooling this surface by means of a suitable quenching medium. Probably the principal item responsible for its development as a manufacturing process for gray iron has been the improvement in the oxygen and acetylene equipment which has made it possible to duplicate results.

Of the large number of analyses or compositions which are classified as gray iron, only those that are called "pearlitic irons" (which usually have combined carbons in the range of 0.60 to 0.80% depending upon the overall composition of the metal) are considered.

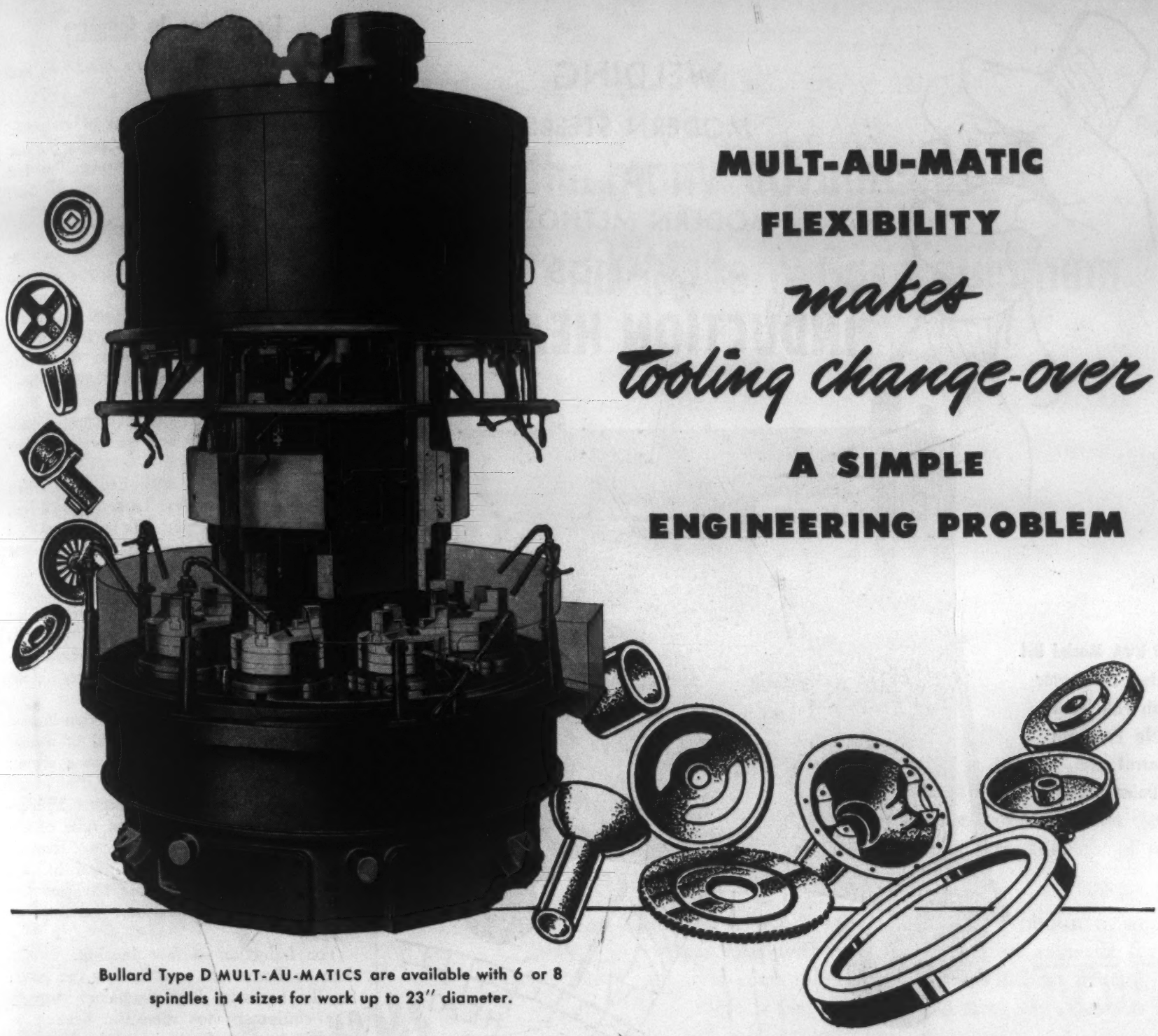
Some of the gray irons suitable for flame hardening fall in the ASTM designation A-48, Classes 40, 50, and 60. Low silicon and, even more important, low total carbon compositions will favor maximum hardness, which, measured with a Rockwell machine or Scleroscope and converted to Brinell, can attain hardness numbers in the range of 550 to 600 BHN.

The casting must be free of foreign materials, such as sand or slag, in the sections to be selectively hardened. Even small particles of sand, which cannot be seen with the naked eye, may explode during the quenching.

As in any other heat treating process, it is of utmost importance that all conditions be accurately controlled. Speeds of torch and quench travel, oxygen and acetylene pressures, volume of quench, and the distances of the torch and quench equipment from the work, are a few of the items that must be held within rather close limits.

It is necessary to keep in mind such factors as the hardenability, critical temperature, and heat conductivity of each type of iron, along with the fundamental standards and specifications. Flame hardening of iron is generally performed on heavy castings thick in section or complicated in shape and unsuited for other methods of hardening. Iron castings, which are subject to wearing action over a localized portion of their surface, can be treated by this process in order to improve wear resistance and thus extend their useful life.

Iron castings, owing to their usual design and to the physical characteristics of the solidifying metal, often contain considerable stresses and should be given a stress relief treatment at as high a temperature as the particular metal will withstand without a structural change prior to flame hardening. (R. H. Olmsted. *The Foundry*, Vol. 74, May 1946, pp. 152-155, 284, 286.)



MULT-AU-MATIC FLEXIBILITY *makes* *tooling change-over* A SIMPLE ENGINEERING PROBLEM

Bullard Type D MULT-AU-MATICS are available with 6 or 8 spindles in 4 sizes for work up to 23″ diameter.

If a Bullard Mult-Au-Matic means to you a special-purpose, quantity-production machine for turning out thousands of parts in continuous process, you are only half right. You have overlooked its proved versatility . . . its ease of change-over.

Change-over from one type of work to another is comparatively simple with Bullard Mult-Au-Matics for three reasons:

1. Universal, Convertible Double-Purpose and Auxiliary Heads are quickly set up for new boring, turning, facing, threading, grooving and drilling operations on all classes of castings, forgings and cut-off bar stock.

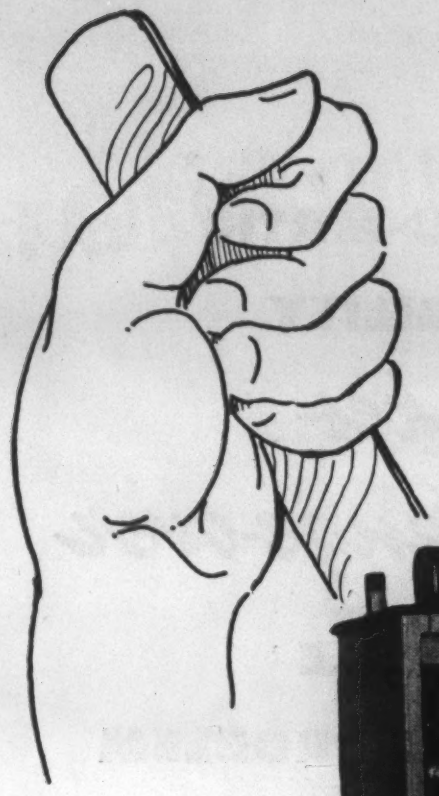
2. Each tool head permits selection of 82 standard rates of feeds completely independent of any other head . . . with other rates possible by simple gear changes.

3. Each spindle may be set for any one of 41 independent speeds.

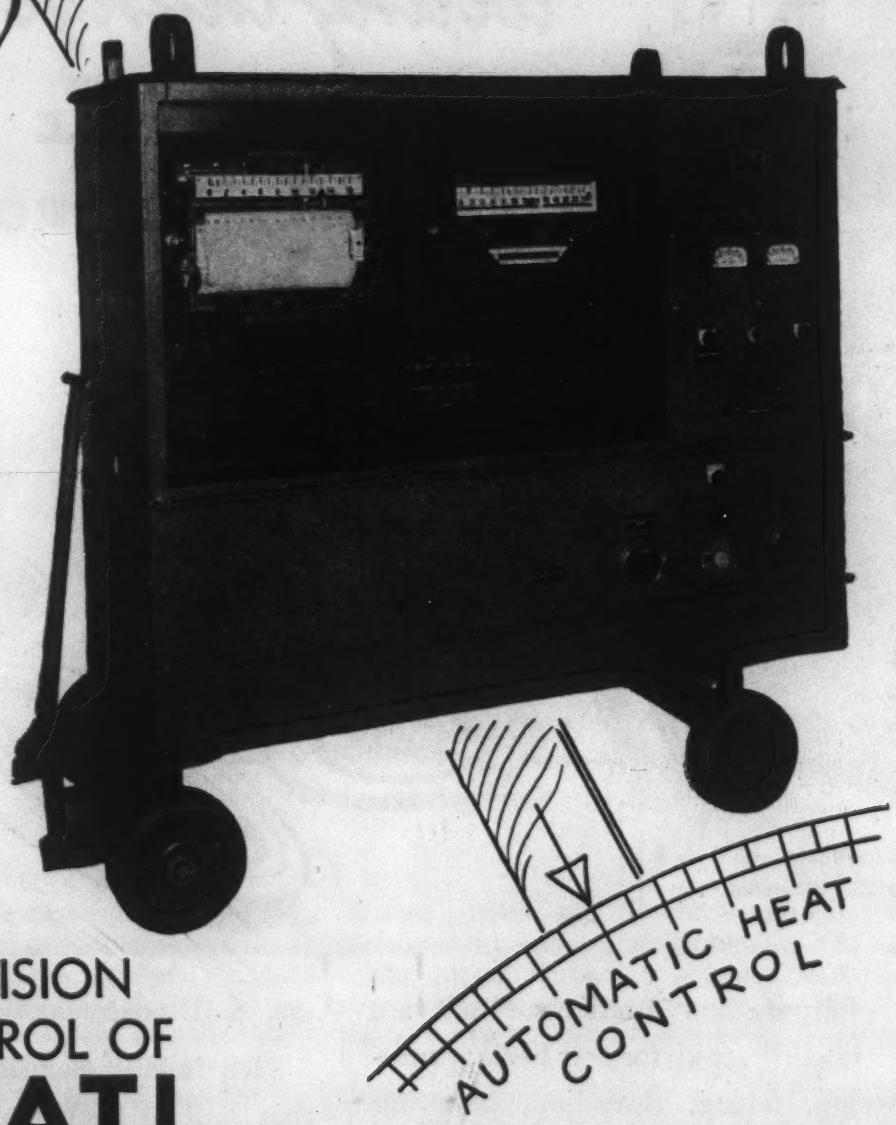
Such in-built flexibility suggests that Bullard Mult-Au-Matics may fit diversified work schedules for which you may never have considered them. It costs you nothing to talk things over with a Bullard sales engineer. In the meanwhile, write for Bulletin 7-6-45 which gives complete specifications of Bullard Type D Mult-Au-Matics. The Bullard Company, Bridgeport 2, Connecticut.

BULLARD

BULLARD CREATES *NEW METHODS* TO MAKE MACHINES DO MORE



WELDING
MODERN STEELS
BY
MODERN METHODS
DEMANDS
INDUCTION HEATING



60 KVA Model BH Induction Heater with Full Heat Cycle Program Control and 6 Point Recorder

FOR PRECISION
CONTROL OF
HEAT!

INDUCTION HEATING by the **SMITH DOLAN SYSTEM**
Plus The New **HEAT CYCLE PROGRAM CONTROL**
Gives all this and more.—Precision control of **PREHEATING FOR WELDING** and **NORMALIZING AFTER WELDING** is the only efficient method for joining modern alloy steels.

MODERN—SELF-OPERATING—COMPLETE!

Once the metallurgical heat-cycle for the steel has been determined, it is only necessary to set the controls, and the machine shown above will deliver this program from start to finish! In addition, recorded charts keep permanent records for duplication of results. A complete unit for efficient performance. Temperatures up to 1750° F. readily obtainable.

ELECTRIC ARC, Inc.

152-158 Jelliff Ave. Newark 8, New Jersey

Electronics in Industry

Condensed from "Southern Machinery and Metals"

The uses and applications of electronic gear are not all as spectacular as the popular press might indicate. During the last several years, especially during the war, more efficient controls for manufacturing methods and equipment, more accurate inspection and test devices and improved industrial safe-guards have been developed that utilize electronic circuits.

One of the most widely used of the industrial electronic equipments is high frequency, or electronic, heating. There are two general methods of electronic heating: "induction heating" and "dielectric heating". Metals (good conductors of electricity) can be heated and melted by induction methods.

Dielectric heating is applied to materials that are nonconductors. To accomplish this, the nonconductive materials are placed in a high frequency electrostatic field (between the plates of a large condenser). The radio frequency current fed into the condenser sets up a field of such characteristics that the material is heated. For induction heating, the metals to be heated or melted are merely placed within a coil carrying the high frequency current.

The generator used for induction heating may be either a motor (diesel or electric drive) driven or a vacuum tube circuit; motor-generators are used for frequencies less than 10 kc. while the higher frequencies are produced by vacuum tube oscillators. For melting metals, the lower frequencies are employed (10 kc. and below), hence melting furnaces may have either a motor-generator or vacuum tube power supply.

For induction surface heating, vacuum tube oscillators are used as they can generate the necessary high frequency currents. The equipment for dielectric heating requires very high frequencies—in the neighborhood of 10 mc. (10 million cycles)—so vacuum tube generators are a must.

Some of the industrial uses of induction heating are:

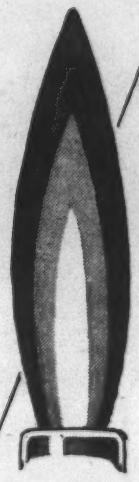
1. Surface hardening of metals to very close tolerances and in extremely short time cycles
2. Tempering of certain types of hardened parts
3. Brazing and soldering
4. Flowing (or uniformly distributing) metallic coatings over a surface
5. Baking protective or decorative finishes on metal parts
6. Detonation of explosive rivets located in inaccessible locations

Dielectric heating, likewise, has a list of important industrial uses:

1. Seasoning, drying, bonding or gluing wood and wood products
2. Preheating of plastic molding forms
3. Processing and curing rubber and plastic materials
4. Baking abrasives under pressure
5. Baking resin bonded abrasives to cure the bond after molding or pressing
6. Drying and/or heating threads and cloth in textile mills and paper during its manufacture

Some of the many advantages of Gas and Modern Gas Equipment

- Dependability
- Versatility
- Simplicity
- Minimum Capital Investment



When the operator turns on the Gas control, he knows that this modern fuel will go to work at once, evidence of its dependability.

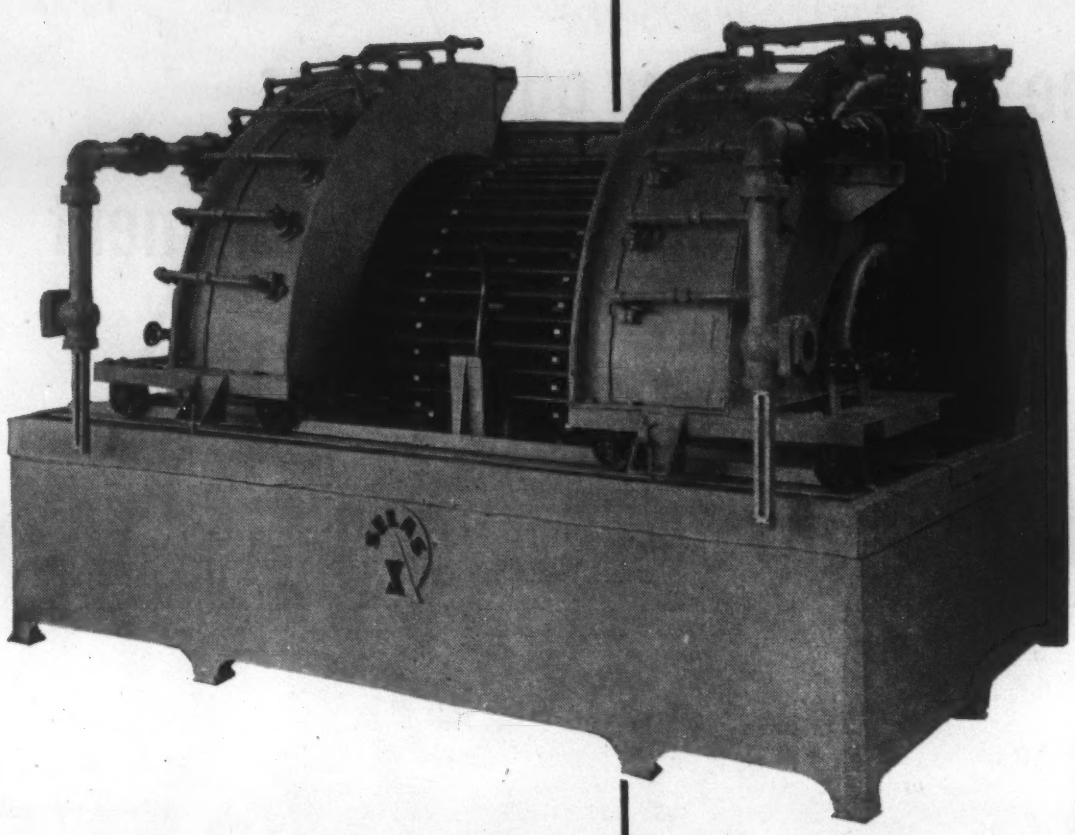
No matter what special conditions obtain in your plant, Gas will be found the most versatile fuel. It is adaptable to any problem in heat treating—there is Gas equipment to meet any situation in the application of heat industrially.

Gas equipment is the easiest to introduce to any production system. Gas works with or without a furnace; there is no other source of heat for plant operation that can surpass this modern fuel in simplicity of equipment, yet do such a successful job.

For the benefit of the established enterprise or the new venture, it is well to know that Gas and Gas equipment require, usually, only minimum capital investment. That is because Gas equipment is modest in first cost, dependable, versatile in application, simple to utilize, economical to operate and requires no investment in stored fuel. The Representative of your local Gas Company is always available for consultation on any industrial problem requiring heat.

THE TREND IS TO GAS
FOR ALL INDUSTRIAL HEATING

AMERICAN GAS · ASSOCIATION
420 LEXINGTON AVENUE, NEW YORK 17, N.Y.



INCREASED PRODUCTION

DECREASED UNIT COST

with a continuous-line heat-treat tool

This machine end-anneals brass tubes rapidly—lowers unit costs and improves metallurgical results. It puts heat treatment in the production line.

Function-fitted combustion—the Selas way—makes this performance possible. Production rate is 2400 per hour; tubes from 1½ to 2 inches in diameter and from 12 to 54 inches in length are accommodated by simple adjustment. Close time-temperature control assures identical heat treatment to strict metallurgical specifications—uniformity therefore is automatic.

To meet today's competition put your heat treating department on the production line. Selas can engineer it. Write today.

Improved Heat Processing

SELAS CORPORATION OF AMERICA PHILA 34 PA

7. Heating and cooking foods (drying, dehydrating, sterilizing, pasteurizing, baking, roasting, and the defrosting of large quantities of frozen foods)
8. Sealing packaged foods

The cost of electronic devices is somewhat higher than that of older types of equipment, averaging $350 per kw. output for induction heating equipments, and $525 per kw. output for dielectric heating gear. Maintenance, replacement of parts and operating costs are low.

The efficiency of properly utilized electronic equipments is 50 to 60%; industrial vacuum tubes have lives averaging 2000 hr. and maintenance charges on many of these devices run about 5% of the purchase price. Operating costs (total) rarely exceed 10 cents per hr. per kw. hr. of output (based on 10-yr. life of the equipment and the above mentioned maintenance and replacement figures).

Costs are further lowered by the remarkably short operating cycle possible with electronic heating devices and by the use of unskilled labor (most of these equipments are fully or semi-automatic). Accuracy of treatment is very high, reducing rejects and improving quality.

Other outstanding applications of electronic circuits to industrial problems are:

1. Electronic sizing gages (wholly automatic or manually fed)
2. Photoelectric pyrometers for recording and/or controlling temperatures within the range of 1600 to 3500 F
3. Sizing and weighing devices for measuring overall thicknesses, thicknesses of electroplated or dipt coatings, and weights
4. Electronic counters and timers
5. Welding controls

[6. *Precipitation of dust particles from the air in air conditioning systems*
7. *Electrostatic painting and detearing (applying very uniform paint and enamel coatings under the influence of electrostatic fields)*—The Editors.]

(M. C. Walker. *Southern Machinery & Metals,* Vol. 2, June 1946, pp. 20-24.)

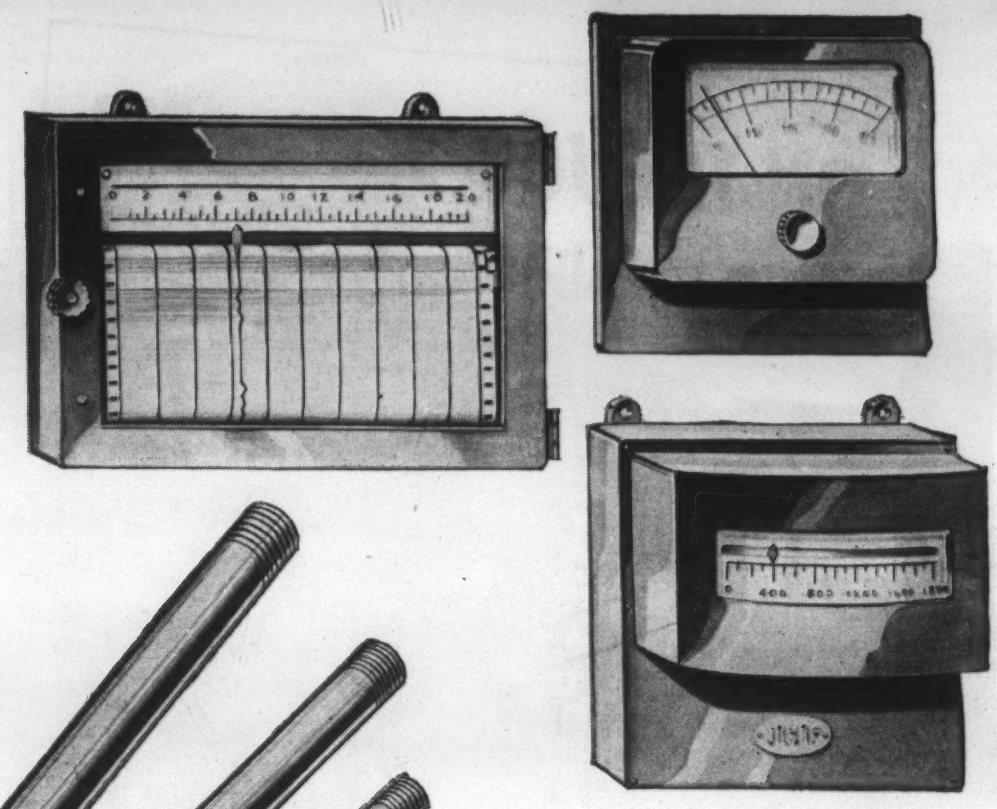
Product Enemy No. 1

Condensed from "Modern Industry"

Wartime research found new ways to fight mildew or fungus that attacked all sorts of military goods from walkie-talkies to tents. Fungi that causes mildew are believed to thrive only in the tropics, but actually they thrive where humidity goes higher than 80% and temperature climbs above 75 F. Such conditions generally exist throughout the United States. There may be more wood-rotting fungi in Alaska than in the warm but arid areas of the United States or central Mexico.

If moisture gets sealed in and the package exposed to room temperatures, conditions are perfect for mold growth. Fungi are simple forms of plant life that grow on materials that supply them with food. Such materials include wood, cotton, felt, adhesives, paints, papers, varnish, leather, waxes, cement, cordage, many plastics and rubber. Besides eating away materials they throw

If you use these



choose these

INCONEL*

Thermocouple Protection Tubes

for more dependable temperature control

STANDARDIZE on Inconel thermocouple protection tubes, and you...

...minimize operating interruptions caused by short-lived tubes

...eliminate dangerous time lag in response to temperature changes.

Inconel tubes are seamless rolled...they withstand high temperatures . . . give longer protection against corrosive, oxidizing and reducing atmospheres...resist embrittling effects of carburizing and nitriding.

Inconel's dense, uniform walls provide greater impermeability to gases harmful to thermocouples.

HIGH STRENGTH AIDS RESPONSE

Inconel tubes can stand severe bumps and jolts. As a matter of fact, the superior hot-strength of Inconel has frequently made this high-Nickel alloy the choice even where corrosion was not a problem.

This greater strength also makes possible *thinner* walled tubes...and quicker response.

NO GREATER COST

Excepting those tubes used for low temperatures, seamless, drawn Inconel tubes cost no more in the long run than the ones you're now using.

READILY AVAILABLE

Inconel thermocouple protection tubes, with one end closed and the other end threaded, are available in standard diameters.

Your regular supplier or instrument manufacturer can furnish any size or length with either standard or extra-heavy wall thickness.

*Reg. U. S. Pat. Off.

Specify

THE INTERNATIONAL NICKEL COMPANY, INC., 67 Wall St., New York 5, N. Y.

INCONEL...for long life at high temperatures

(80 NICKEL - 14 CHROMIUM)

ON THE JOB SINCE 1919
...NO REPAIR PARTS FURNISHED

KINNEY
ROTATING PLUNGER PUMPS

After more than a quarter-century of constant service, these Kinney SD Rotating Plunger Pumps, installed in 1919, are still (according to the operators) "the best pumps ever built". This enthusiastic report speaks for itself:

"From a strictly hard, practical operating standpoint the story is short, sweet and simple. No matter what the oil, or temperature outside, each pump will go right up to 1250 bbls. per hour with an average pumping pressure of 80-90# for heavier oils, and 40-50# for lighter. Nothing to it. No change for past 25 years . . . Discharge line out onto dock is cold in winter and pumps have to be started with by-pass open . . . Gradually come down on it, keeping at just about 90# (relief set at 100#), and when you get it down — there is your 1250 bbls. and no further attention.

That's all. That's the whole story. Been doing that since 1st World War, winter and summer. No difference in flow, hot or cold, light or heavy oil."

It's not a *new* story — just *another* history of Kinney reliability — but such reports on hundreds of successful installations constitute an impressive record for Kinney Pumps.

Write for Bulletin 18A.

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Horrock Roxburgh Pty., Ltd., Melbourne, C. I. Australia
W. S. Thomas & Taylor Pty. Ltd., Johannesburg, Union of South Africa

WE ALSO MANUFACTURE VACUUM PUMPS, CLUTCHES AND BITUMINOUS DISTRIBUTORS

off organic acids which even etch glass, say, of optical instruments. They decompose paint films on metal surfaces and cause corrosion.

Chemical treatments that protect against fungi may be grouped under four main types: metallic naphthenates, phenolic compounds, mercury compounds, and pure organics. Copper naphthenates, in type 1, only recently won wide recognition as outstanding fungicides, protecting all sorts of war-time products. Peace-time applications now opening from copper and zinc naphthenates are very extensive.

These fungicides are applied by pressure-impregnation, dipping or coating. Some types are for use only by commercial treaters, others by processing and fabricating plants and others by end-users.

Few, if any, are perfect. Some treatments cause dermatitis; others allow molds to form, harmless but obnoxious; others have an offensive odor, are sticky and hard to handle, cannot stand high heat, add weight, etc. (*Modern Ind.*, Vol. 11, May 15, 1946, pp. 34-37.)

Electropolishing Metals to Obtain Surface Finish

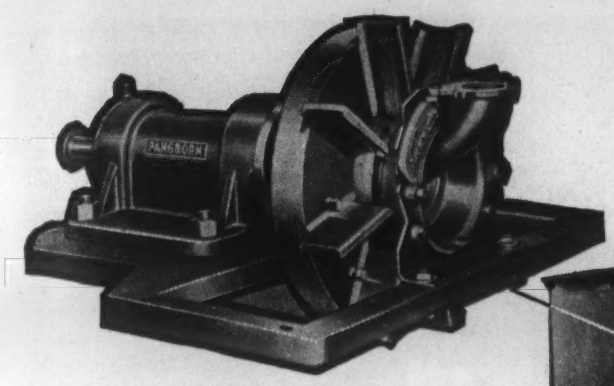
Condensed from "Product Engineering"

Electropolishing finishes metal surfaces without mechanical work being done on the metal. The process might be considered as electroplating in reverse. The part to be polished becomes an anode instead of the cathode as in electroplating. When the current is applied a minute film on the surface is dissolved and flows off the surface into the electrolyte.

Solutions of sulphuric and phosphoric acids are used in commercial electropolishing for many of the common metals and alloys (process patented by Battelle Development Corp.). Commercial electropolishing of stainless steels is done in solutions comprising 55 to 60% citric acid, 15 to 20% sulphuric acid and water (process patented by Rustless Iron & Steel Div. of American Rolling Mill Co.). Other types of solutions are available. Generally they contain phosphoric acid, or sulphuric and phosphoric acids, plus organic material.

The most frequent application is finishing for appearance. Since electropolishing gets into pits and depressions, stainless steel castings can be easily polished by this method. The electropolishing of electric appliance parts eliminates the hand operations. Brass stampings can also be electropolished, either before the nickel and chromium plating or after the bright nickel coating.

Costume jewelry, intricate in design and shape, can be electropolished. A pebble finish can be obtained by preparing the surface by shot or sand or vapor blasting before electropolishing. Sometimes electropolishing can take off burrs from stamped edges of complicated shapes and from otherwise inaccessible areas. Electropolishing can also be used for the removal of heat scale. With this process dimensions on parts can be maintained as electropolishing removes metal from all surfaces uniformly.



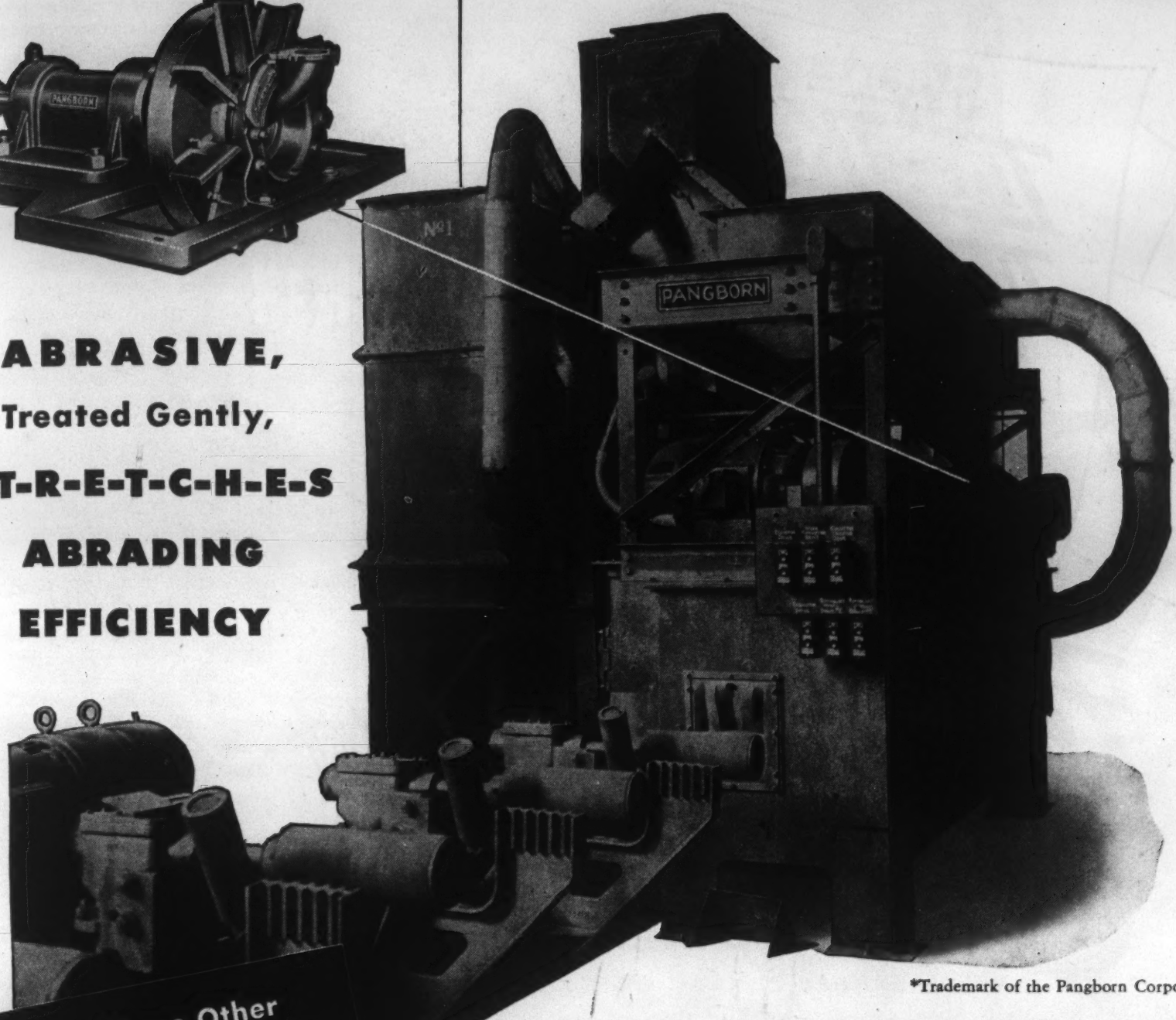
ABRASIVE,

Treated Gently,

S-T-R-E-T-C-H-E-S

ABRADING

EFFICIENCY



And These Other PANGBORN FEATURES Save You More Time and Money

Straight-line handling. In ROTOBLAST Special Machines and Cabinets, straight-line handling of work is a Pangborn-originated development that increases production. Work passes on conveyors arranged so that the work receives maximum coverage in blast stream.

Long-life vane head plate. Made to the same specifications as the vanes themselves. Service life up to 3,000 hours, depending on nature of work and abrasive.

Abrasive reclaiming. The Pangborn system of stratification and air washing dependably separates usable abrasive from fines and refuse and returns it to ROTOBLAST unit for re-use. Send coupon now for Bulletin 2120 on Pangborn ROTOBLAST Special Machines. And for any type of blast cleaning equipment — airless or compressed air — "Come to Pangborn," *world's largest manufacturer of blast cleaning and dust control equipment.*

*Trademark of the Pangborn Corporation

No Other Airless Blast Machine Has This Cost-Saving Feature.

The more punishment the abrasive takes before it strikes the work, the shorter its life.

To stretch abrading efficiency in ROTOBLAST* cleaning — Pangborn designed an improved method of feeding abrasive onto the moving vanes at a velocity equal to the speed of the moving vanes. A uniquely designed feed cup is the key part — and its function is to accelerate speed of abrasive and deliver it to heel of vane smoothly — without shocks. No other airless unit has this advantage — which saves maintenance and replacement parts on machines, and assures continuous abrading efficiency of abrasives for a substantially longer period.

Pangborn

PANGBORN CORPORATION, HAGERSTOWN, MARYLAND

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Gentlemen: Please send me free Bulletin 2120 on ROTOBLAST Special Machines. Check also for information on: ROTOBLAST Rocker Barrels ☐ ROTOBLAST Tables ☐ Air Blast Rooms ☐

Name .....

Company .....

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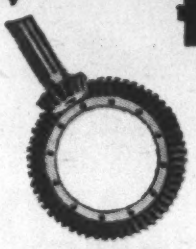
"right cutting oils"

Fundamental...

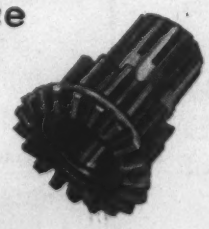
to good gear cutting



TOUGH STEELS, deep cuts, high finish requirements characterize most gear cutting operations. Tearing, scuffing and metal pickup are often serious machining problems to makers of gears.

Wise gear manufacturers avoid these difficulties by specifying Stuart's high lubricity, high anti-weld type cutting oils for gear hobbing, shaping, generating, or finishing operations.

Stuart Cutting Oils and Stuart Engineering Service will help you produce better gears at lower cost.



Write for:
"Cutting Fluids for Better Machining"

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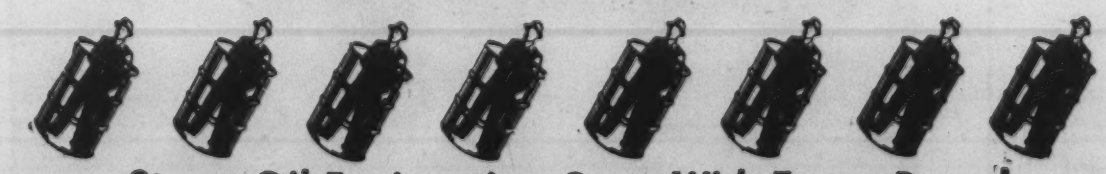
EST. 1865 LIMITED

2745 SOUTH TROY STREET, CHICAGO 23, ILL.



Stuart Oil Engineering Goes With Every Barrel

Electropolishing has a number of advantages over mechanical methods of preparing surfaces for plating. An electropolished surface is: (1) free from stresses; (2) structurally characteristic of the body of the metal; (3) free from metal fragments and layers of broken-down crystal structure; and (4) not influenced by heating effects from mechanical working the surface.

Electropolishing can be done in fully-automatic, semiautomatic, or manually operated equipment, and single and multi-stage processes can be set up. (Charles L. Faust. *Prod. Engineering,* Vol. 17, June 1946, pp. 449-451.)

Welding Stainless

Condensed from "Western Metals"

Major variables in welding 18:8 stainless steel sheet are: mechanical arrangement of joint, welding flame, rate of travel, flux, and the steel composition. The highest quality welding of thin sheet requires excellent fitting of the edges of the joint. The last four variables are interdependent in oxyacetylene, electric arc, atomic hydrogen and gas shielded arc welding (electric resistance welding is not discussed). Although the desirability of increasing the silicon content of 18:8 with columbium or titanium has been shown, its effectiveness is not independent of the heat input and flux.

A minimum heat input is usually recommended to prevent carbon pick-up in the weld. Pickling after welding may serve as an automatic inspection for carbon pick-up, which decreases the corrosion resistance of the weld. If the weld gets too hot, there will be a significant loss of some of the alloying elements: titanium, columbium, manganese, chromium and nickel. The effects of oxidation may be mitigated to some extent by a suitable flux.

The melting range, viscosity, surface tension and specific gravity of the molten flux are important. A factor of varying degrees of importance in welding is the flow-out at the interface between the weld melt and the base metal. The welding flux and its fluidity exert an influence on the joint geometry in this respect. One problem in lap welding of thin sheets is to provide a joint contour of a small stress concentration factor.

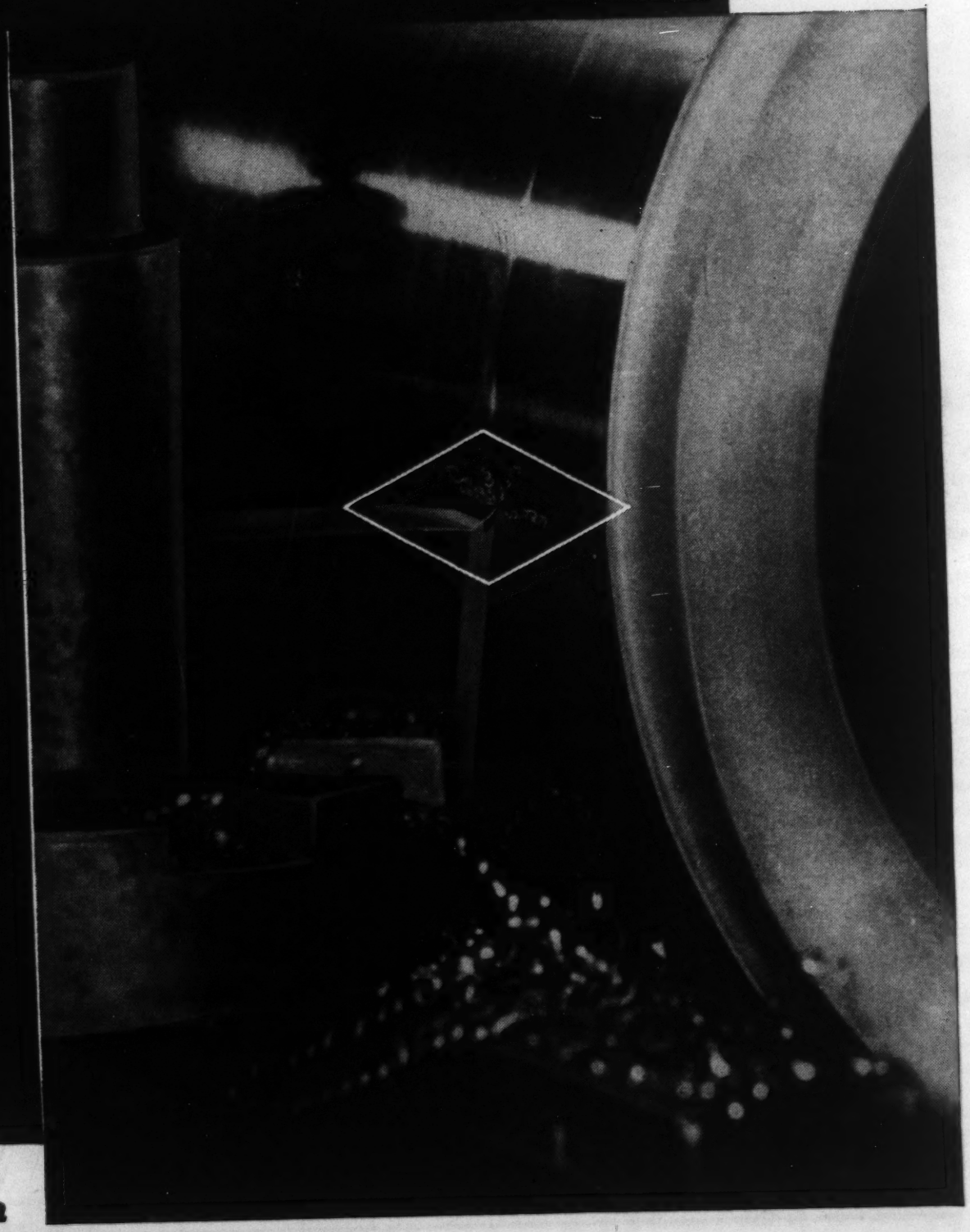
Anything that can be done to simplify the operator's job by giving quantitative instructions is worth while. As a by-product of this investigation of welding, a special, light-weight torch has been developed for hydrogen welding. This torch has cut down operator fatigue to a noticeable degree. (H. A. Campbell. *Western Metals,* Vol. 4, Feb. 1946, pp. 17-19.)

Cleaning Zinc Alloys

Condensed from the "Monthly Review" of The American Electroplaters' Society

There has been considerable disagreement in the past years as to whether zinc die castings should be cleaned with sodium silicates or even with compounds containing them. Investigation revealed the following: (1) At 195 F (90.5 C) and a

FIRTHITE



If you have a cutting problem—

Call **Firth-Sterling**

STEEL COMPANY

McKEESPORT, PA. • NEW YORK • HARTFORD • PHILADELPHIA • PITTSBURGH • CLEVELAND • DAYTON • DETROIT • CHICAGO • LOS ANGELES

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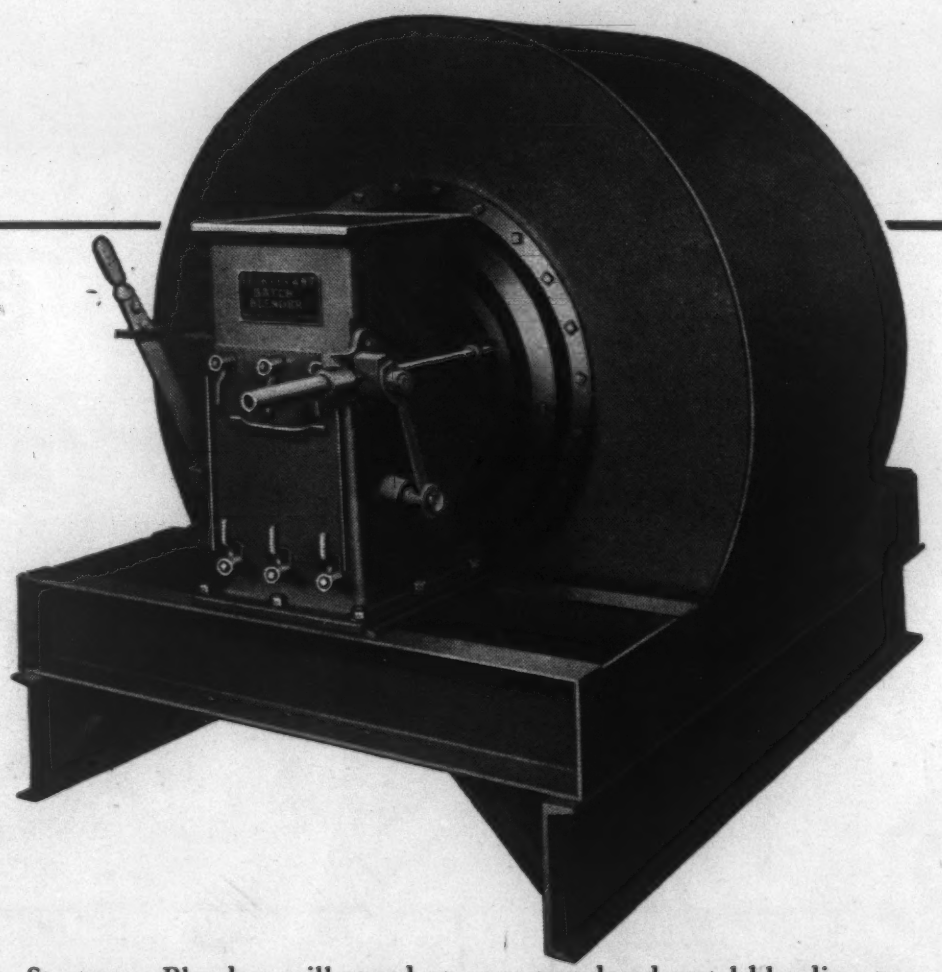
DRY BATCH
BLENDERS
Cut Powder Metal Blending Costs ... Increase Production



Sturtevant Blenders will speed up your powdered metal blending providing perfect homogenous blends regardless of the varying densities, weights or finenesses of the powders.

The 4-way mixing action assures perfect batches with no substances floating to remain unmixed. As materials are received they are picked up by revolving buckets and cascaded from the top of the machine. At the same time the drum revolves forcing the powders from both ends toward the center of the drum . . . while the swinging chute, which is in blending position produces a fourth lateral mixing action.

Heavy rugged construction assures long life. Open-door accessibility permits quick, easy cleaning. Available in sizes from 1000 to 7500 pounds. Write for information.

Sturtevant MILL COMPANY

61 Harrison Square • Boston 22, Massachusetts

Designers and Manufacturers of

CRUSHERS • GRINDERS • SEPARATORS • CONVEYORS
MECHANICAL DENS and EXCAVATORS • ELEVATORS • MIXERS

current density of approximately 1 amp. per sq. decimeter, zinc or zinc casting alloys can be cleaned anodically in 3% solutions of sodium metasilicate or sesquisilicate. (2) Under the same conditions the sodium di- and tri-silicates give heavy white deposits on the anode.

(3) The formation of the anode deposit is not dependent on the silica content but on the $Na_2O:SiO_2$ ratio in the silicates employed. (4) There are no deposit or attack on zinc or zinc alloy cathodes with the silicates alone under any of the above conditions. (5) Lower temperatures or lower concentrations increase the probability for the formation of anodic deposits. (6) Higher concentrations of sodium metasilicate cause brown streaks on the cathodes at 9% and darken the anodes slightly at 8 and 12%.

(7) A definite minimum concentration of each chemical is required to prevent the formation of anodic coatings on zinc. (8) Three per cent solutions of sodium metasilicate, sesquisilicate or sodium carbonate can be used safely for anodic cleaning; the same concentrations of these and of trisodium phosphate, tetrasodium pyrophosphate and sodium metaphosphate are safe for cathodic cleaning. (9) It is unnecessary to use soft water in the preparation of the baths.

(10) Rinse water should be as free from dissolved solids as possible. (11) Higher current densities increase the tendency for deposits to form on the anodes. (12) The conductivities of 3% sesquisilicate and metasilicate solutions are high as compared with those of other materials except sodium hydroxide. (13) The electrical resistance rises rapidly when deposits form on the electrodes.

Thus, the question originally posed can be answered by saying that not only can sodium silicates be used in cleaning zinc and zinc alloys, but when correctly selected silicates are used under controlled conditions, both attack and deposit on the metals are eliminated. (Fred Hazel & William Stericker. *Monthly Rev.*, Vol. 33, Apr. 1946, pp. 373-388.)

Pickling

Condensed from "Sheet Metal Industries"

The pickling of steel and iron alloys is generally carried out in solutions containing either sulphuric acid, ferrous sulphate and water, or hydrochloric acid, ferrous chloride and water as their main constituents. Economically, sulphuric acid has some advantages over hydrochloric acid. The only drawback of sulphuric acid that can be detected at first glance is the cost of heating the pickling solution.

Sulphuric acid solutions give good results when (1) the acid content is high enough; (2) the pickling temperature is well chosen; and (3) the ferrous sulphate content of the solution is kept reasonably low. The pickled objects carry a black smudge

CLEANING AND CORROSION TIPS

Issue No. 4

AUGUST 1946

CASE NO. 810

PLAN EFFICIENCY LIKE THIS . . . WATCH IT LOWER YOUR PRODUCTION COSTS IN UNEXPECTED WAYS

Surprisingly often, the solution of one problem brings a chain of secondary benefits which are sometimes not anticipated when the basic problem is tackled.

This was clearly revealed in the case of a certain wire manufacturer. His production department was troubled by the rapid wearing out of wire-drawing dies. Efforts to uncover the cause had failed. All operations of the drawing machine had been checked. Inspection of the die stands showed that the die pockets had been accurately machined. The approach, bearing, length and polish of the dies were suitable for the type of wire being drawn.

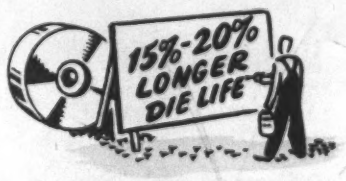
So, the next time the Pennsalt man called, the wire mill supervisor asked his study and advice on the problem.

The Pennsalt man knew that insufficient cleaning would leave material such as smut and scale on the wire which would interfere with subsequent drawing. At the same time he had to guard against over-cleaning, for fear of a pitted and rough surface. He knew that either of these conditions would lower the life of the dies, and lower production.

Working together, the Pennsalt man and the cleaning foreman found a Pennsalt Cleaner which cleaned the wire thoroughly. Result: the tungsten carbide dies in this plant now last 15%-20% longer.

The technical "know-how" of the Pennsalt man in the proper application of his products gave another boost to industrial efficiency. It did more than solve the immediate problem . . . it cut out other expensive factors, too, as the diagram below indicates!

WORKING TO GET THIS:



ELIMINATED THESE TOO:

CASE NO. 802

Pickling Bath Now Lasts 7 Weeks Instead Of 1

Galvanizing also improved

A galvanizing company, using sulphuric acid pickle prior to galvanizing, had found it necessary to renew the bath every week.

During a regular call, the Pennsalt man suggested the use of Pennsalt PM-40 acid pickling inhibitor to lengthen the life of the bath, and to improve pickling results at the same time. With the inhibitor added, the acid does a thorough job for seven weeks before being dumped, and there is less metal lost than ever before.

PM-40 is free-rinsing and minimizes hydrogen absorption, an ideal inhibitor to use prior to galvanizing or enameling.

12 of the Nation's 15 leading strip mills are regular users of Pennsalt Cleaners. Orthosil is an example of these products which are anhydrous, concentrated, free-flowing materials primarily developed for heavy duty cleaning of ferrous metals.

CHECK CHART

Use it to help maintain the efficiency of your cleaning

RINSING

- Water temperature maintained ?
- Rinsing time checked ?
- Clean water ?

ANODIC/CATHODIC CURRENT

- Amperage correct ?
- Current density maintained properly ?
- Clean, well-insulated connections ?

CHEMICAL BATH

- Correct solution analysis ?
- Correct temperature ?
- Timing carefully controlled ?

PICKLING

- Correct solution ?
- Temperature constant ?
- Would acid inhibitor improve the pickling ?
- Proper corrosion resistant tank ?

DRYING

- Satisfactory drying conditions ?
- Could drying time be cut ?

THE LAB NOTEBOOK

Comparisons of metal cleaners is a never-ending job in our laboratories. Such equipment as the Du Nouy Interfacial Tensiometer, the X-Ray, the spectroscope and other optical equipment are commonly used as aids in these comparisons.

The best scientific equipment is often supplemented by practical ingenuity such as in the instance where a quick method of determining the relative wetting out properties of cleaners was required in a series of tests. Equal weights of ordinary steel wool were rolled into balls and placed in solutions of the various cleaners. The time required for the ball to sink to the bottom of the beakers gave a satisfactory qualitative comparison of this property of the cleaners. Such simple improvisations frequently serve as useful adjuncts to precise scientific equipment in finding the answers to important metal cleaning problems.

CASE NO. 841

Cleaning Time Reduced From 15 Minutes To 11

50% saving in cleaning material

In removing ammonium chloride flux from cold rolled galvanized steel parts prior to Bonderizing and painting, a metal products manufacturer had been getting consistently unsatisfactory results.

The Pennsalt man studied the problem, and once again his technical knowledge provided the answer. First, he started the cycle with a hot water rinse, ridding the parts of the acidic, water-soluble, free ammonium chloride. Then came a brief immersion in a solution of Pennsalt Cleaner #35, followed by rinsing and subsequent Bonderizing.

All traces of the flux were completely removed, while the cleaning time was reduced from 15 minutes to 11, and consumption of cleaning material slashed 50%.

Any Corrosion Problems?

Training and wide experience equip the Pennsalt Man to solve a broad range of problems in the metalworking industries. This includes not only cleaning and finishing processes, but also problems concerning corrosion, and corrosion-resistant construction. If you have a corrosion headache, why not ask the Pennsalt Man's advice?

The Pennsalt Man is trained to help you produce better cleaned products at a faster rate and at lower cost. If you would like to see him, write to Dept. MM-8. If your problem is urgent—wire, and he will call immediately.

PENNSALT

96 YEARS OF SERVICE TO INDUSTRY

PENNSYLVANIA SALT MANUFACTURING COMPANY

Chemicals

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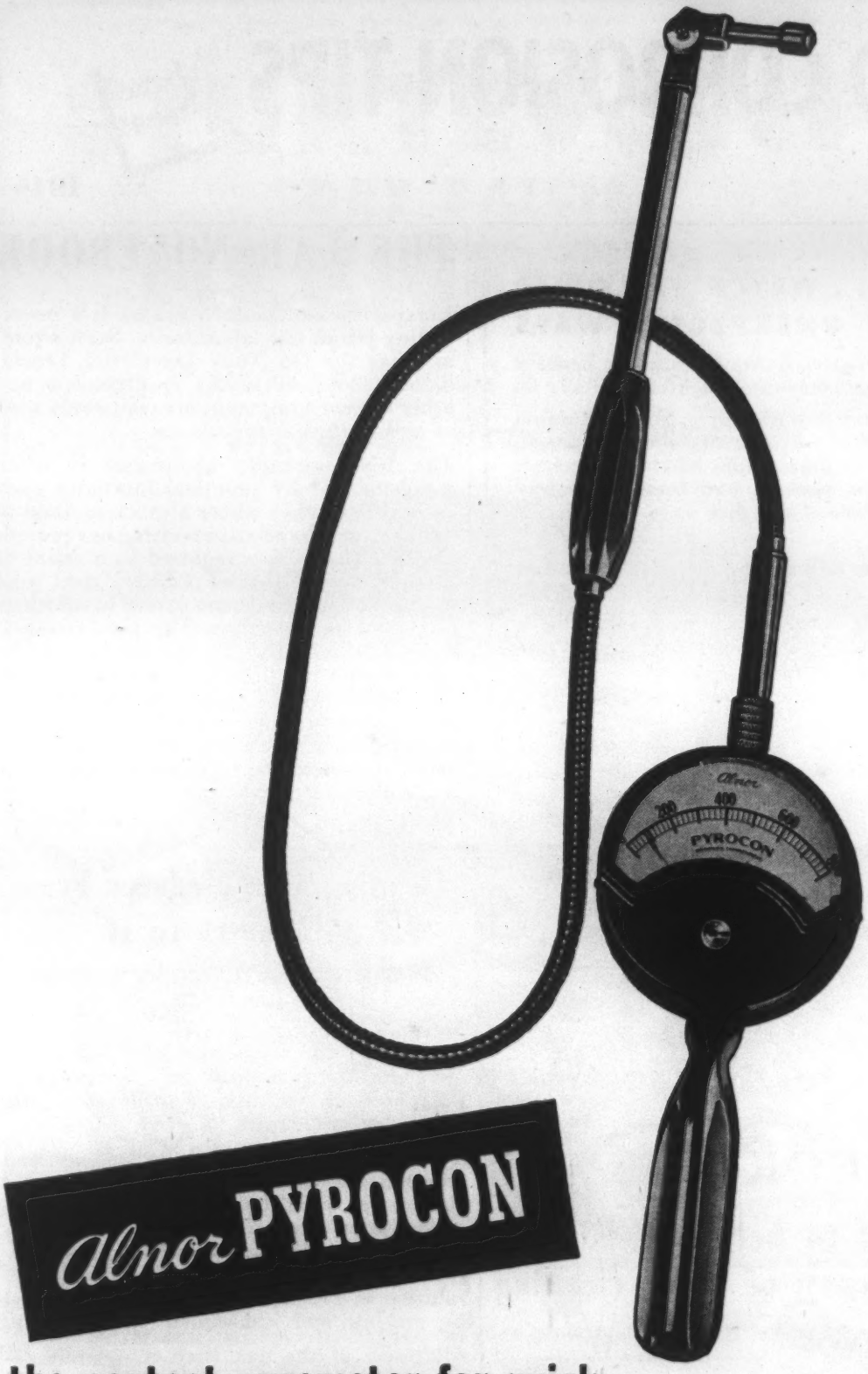


the contact pyrometer for quick, accurate surface temperatures

Designed to meet foundry and industrial plant needs, this all-purpose surface temperature pyrometer provides readings in a few seconds of molten metals, liquids, bulk materials, and flat or curved, stationary or moving surfaces. The rugged, shock-resisting pyrometer movement may be used with any of eight standard thermocouples, interchangeable without adjustment or re-calibration. Choice of rigid or flexible arms. Built in several standard scale ranges, 0-300 to 0-1200 F. Write for bulletin with complete description.

ILLINOIS TESTING LABORATORIES, INC.
420 N. LA SALLE STREET • CHICAGO 10, ILLINOIS

which is a serious problem when the articles must be galvanized or tinned.

Hydrochloric acid is an efficient pickling medium for iron and its alloys; it can be used at room temperature. The reaction product on iron oxide is ferrous chloride, which is highly soluble in water, and thus is very easy to remove from pickled surfaces by rinsing in running water. The main weakness of hydrochloric acid pickling lies in the extreme difficulty of devising and operating a satisfactory method of regeneration of the spent liquors.

The ferrous sulphate evolved during pickling in sulphuric acid solutions has a dangerous influence upon the speed of operation, and there is considerable risk of defects in subsequent enamelling or galvanizing. The author uncovered a method that converts the detrimental amount of ferrous sulphate into ferrous chloride by the action of hydrochloric acid. This balanced action bath makes it possible to keep the $FeSO_4$ content within such limits that its deleterious effects are nullified, besides making for a very high speed of reaction of the solution upon iron and its oxides. (Paul De Lattre. *Sheet Metal Industries*, Vol. 23, Apr. 1946, pp. 685-694.)

Machining Glass

Condensed from "Industrial Diamond Review"

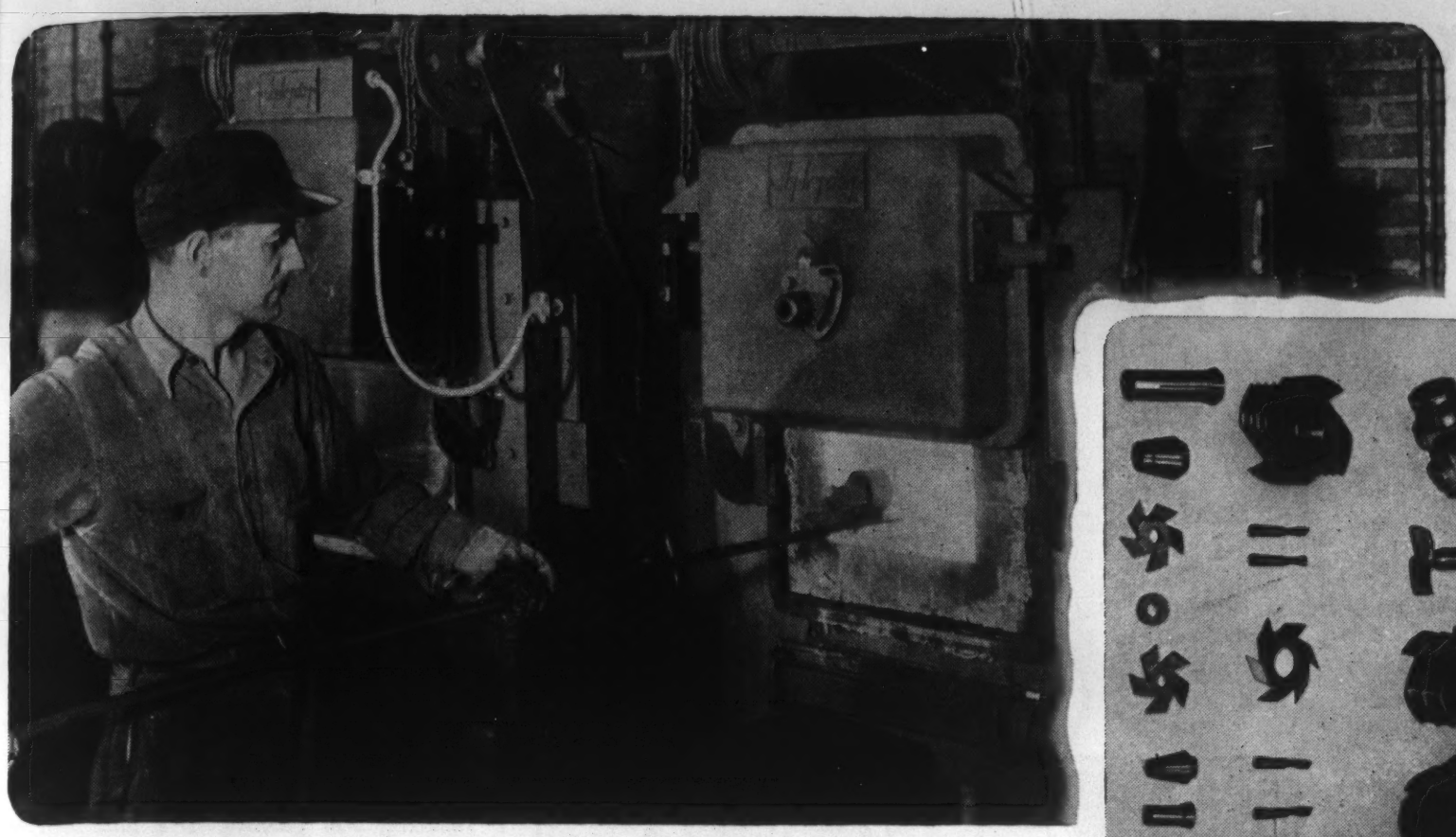
The use of diamond tools in the sawing and grinding of glass is based on two factors: (a) The production of suitable diamond tools of great durability, and (b) production of suitable machines of sufficient rigidity.

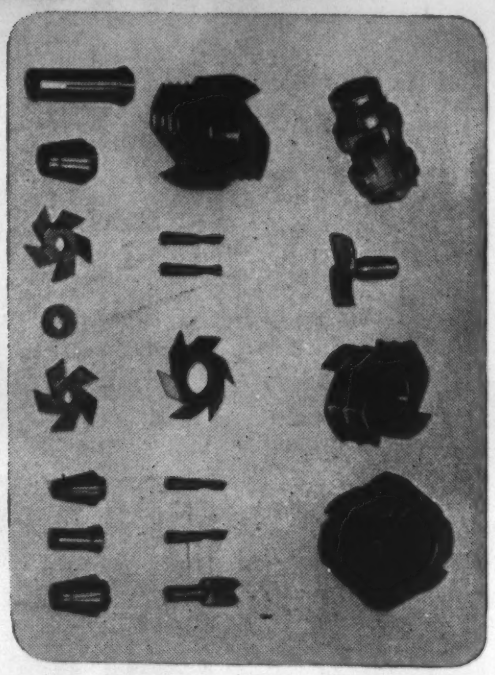
This account is based (a) on tools produced by Impregnated Diamond Products, Gloucester, and (b) on special machines developed by Adcock & Shipley, Leicester (both of England). Operations considered include: grinding of flat surfaces, grinding of cylindrical and conical surfaces, and grinding of spherical faces.

The Adcock & Shipley glass sawing machine has impregnated diamond cutting discs and bullnose cup wheels. The coolant is supplied to the top of the wheel guard and led through pipes to the cutting edge of the sawing blade. The base serves as a reception tank for the coolant, and may be This machine has also found applications in supplemented by a central drainage system. the cutting of porcelain, terra cotta, refractories and marble.

Diamond impregnated wheels are employed for grinding the outside peripheries of circular lenses. These wheels are applied in grades 160/200 mesh and 260/300 mesh. The average life of a 6 x ½ in. wheel is 18 months to 2 years.

In the automatic lens edging machine the grinding wheel speed is 2,300 r.p.m., giving, in the case of a 6-in. dia. wheel, a peripheral speed of 3,450 f.p.m. An indispensable item in connection with the edging machine is the optical centering lathe. Besides centering and setting up, this





ONSRUD hardens high speed cutters without Scale, Carb, or Decarb in LINDBERG HYDRYZING FURNACES

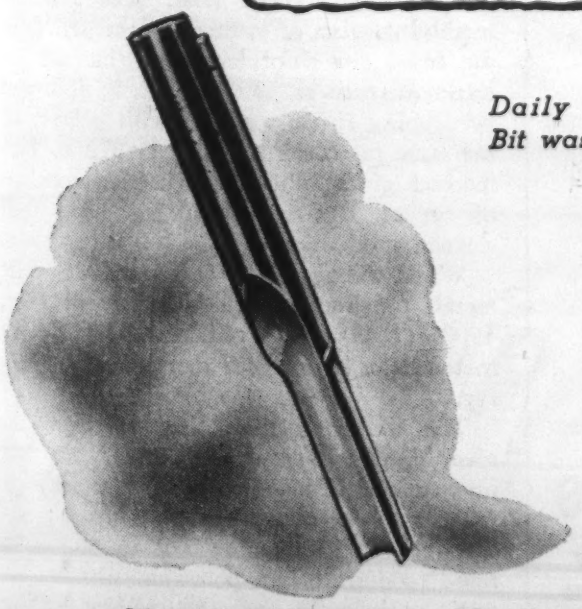
Doubles Production—Eliminates Rejects!

Erick Olsen, Plant Supt. at Onsrud says:

"WE GET MUCH BETTER HARDNESS UNIFORMITY, AND WE AREN'T BOTHERED WITH SCALE OR DECARB. WE'VE DOUBLED OUR HEAT TREAT PRODUCTION, AND WE DON'T HAVE ANY HEAT TREAT REJECTS ANYMORE. —AND MAINTENANCE IS WAY DOWN."

In July 1945 Onsrud Machine Works, Chicago, manufacturers of high speed cutters for routing, shaping, and carving, installed two Lindberg Hydryzing furnaces,—a preheat and a high heat, along with a Lindberg HYCO atmosphere generator. This equipment replaced two conventional non-atmosphere box type furnaces of the same size.

Month in and month out production shows that Hydryzing hardening lengthens the already long operating life of Onsrud cutters.



Daily hardening production on this Onsrud 1/4" Router Bit was increased from 500 to 1000. Some of the reasons:

- . . . With Lindberg furnaces, the entire hearth area can be used. This is because both the front and back areas of the hearth reach and hold the same temperature as the center area.
- . . . Lindberg Furnaces reach hardening heat 25% quicker.
- . . . By eliminating scale, the sand blasting operation was done away with.
- . . . Rejects due to hardening were cut from an average of 50 cutters per 1000 to zero. (This is a fact vouched for by Mr. Olsen.)

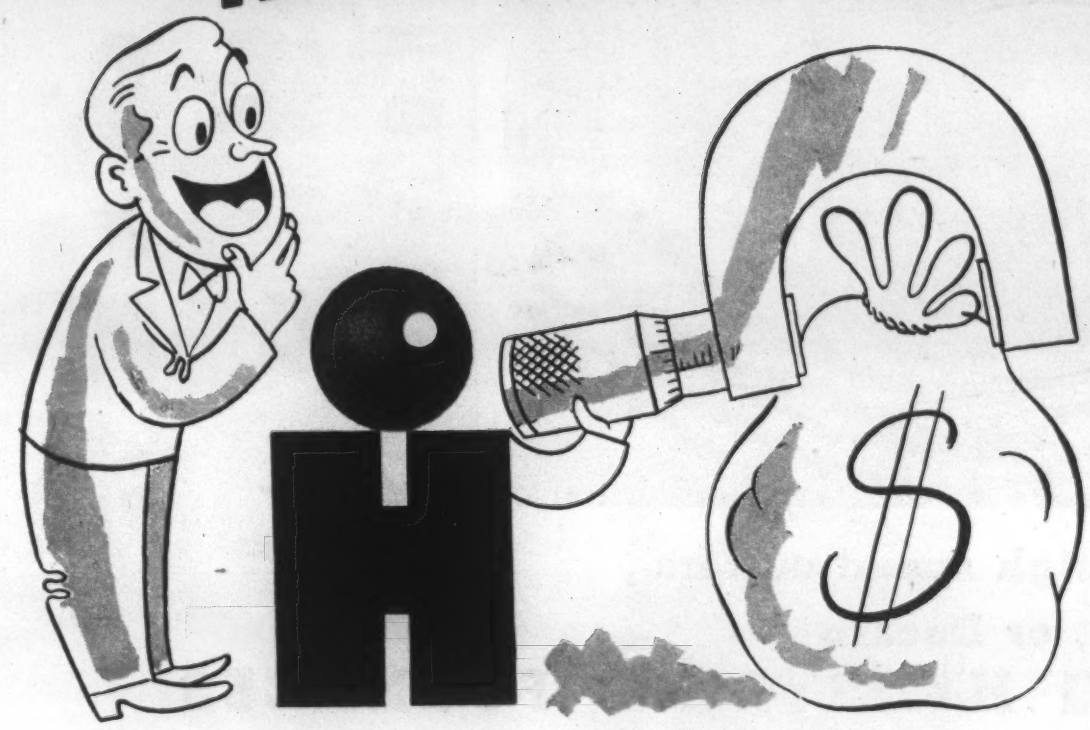
Lindberg Engineering Company, 2451 W. Hubbard St., Chicago 12, Ill.

Write for bulletin 95-hs, "Lindberg Hydryzing Furnaces," and a reprint of an article, "Heat Treatment of High Speed Steel Cutters."

LINDBERG FURNACES

ASK US TO ESTIMATE THE

ACTUAL SAVINGS



YOU GET FROM

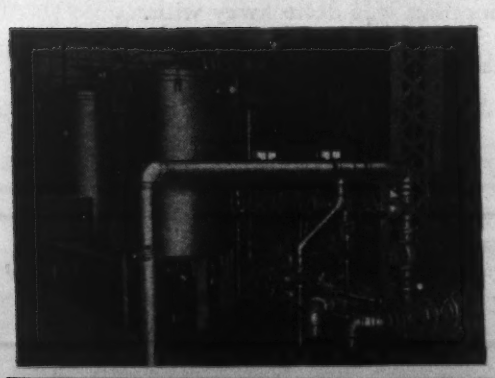
HOFFMAN FILTRATION

★ SAVINGS IN PRODUCTION COSTS

Hoffman Filtration of machine tool coolants, wash oils and other industrial oils increases production, lengthens life of machines, cutting tools and grinding wheels.

★ SAVINGS IN MAINTENANCE COSTS

Machines operate longer cycles without necessity for shutting down to clean out sumps. Some models, with automatic sludge removal, permit nearly continuous operation.



★ SAVINGS IN REDUCED REJECTS

Hoffman filtration, supplemented by Hoffman coolant refrigeration where appropriate, enhances precision finish, aids in maintaining tolerances, and reduces your rejects.

U. S. HOFFMAN MACHINERY CORPORATION
223 Lamson St., Syracuse, N. Y.
COOLANT FILTERS • FILTRATION ENGINEERING SERVICE

lathe can be used for chamfering and edging by hand. (Paul Grodzinski. *Ind. Diamond Rev.*, Vol. 6, Apr. 1946, pp. 101-107.)

The Tinning of Cast Iron

Condensed from a Paper of the Iron and Steel Institute

Cast iron is tinned either to give it a non-toxic, corrosion-resistant coating, or to facilitate the adhesion of a white-metal layer. In view of the difficulty of tinning cast iron directly, the object of this research was to evolve methods for hot-tinning it directly without the application of an intermediate metal coating.

Investigation of modifications of the ordinary tinning processes shows that improved tin coatings can be obtained by reducing acid pickling to a minimum by good mechanical cleaning, decarburizing or machining followed by shot-blasting. The best pickling agent proved to be a cold mixture of sulphuric and hydrofluoric acids (5% sulphuric acid and 5% hydrofluoric acid, by volume).

High-silicon irons, high-carbon irons and annealed irons are of inferior tinning quality. The poor tinning quality of cast iron is shown to be caused mainly by the presence of graphite flakes and sludge after pickling in acids. Treatment of cast iron in fused salts, as an alternative to the processes of degreasing, pickling and fluxing in aqueous solutions, was investigated to reduce the number of preliminary operations before tinning and to avoid, as far as possible, the use of aqueous solutions.

Two new methods of preparing cast iron for tinning are described, both involving treatment in molten salts. The chloride method consists of immersing the article in the fused zinc-chloride-sodium-chloride eutectic mixture at 572 to 662 F, followed by dipping in tin, covered with a layer of the same fused salt mixture, at 572 F. This method gives adherent protective coatings of tin on cast iron that has been well cleaned mechanically.

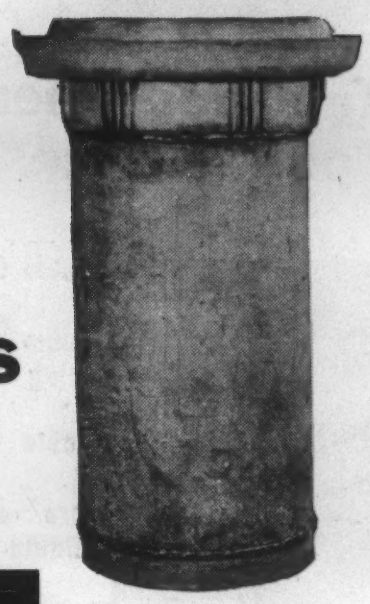
When the cast iron is bonded to white metal, consistant adhesion values of from 4500 to 6300 psi. are obtained. The chloride method can be adapted to tinning by wiping.

The nitrate method was developed to give highly adherent coatings of tin and involves the following steps: light pickling in acid to "open up" graphite flakes; immersion for 15 min. at 572 to 662 F in fused sodium-nitrate-potassium-nitrate eutectic mixture in order to oxidize surface graphite; pickling in dilute hydrofluoric acid to remove the scale formed by the nitrate bath; fluxing and tinning.

Adhesion values up to 8500 psi. are obtained between tin-base bearing alloy and cast iron tinned by this method. Microscopic examination of the bond shows that the tin penetrates cavities formerly occupied by graphite.

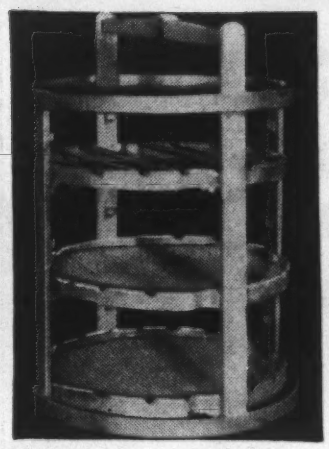
3 WAYS TO FIGHT HEAT!

INCONEL Retorts



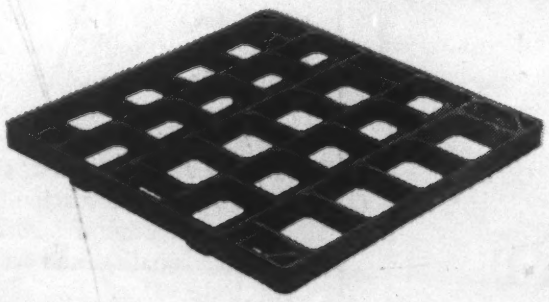
One of a complete line of Stanwood Inconel retorts. Reports show an average service life at least 50% greater than that of ordinary retorts... *frequently several hundred per cent.*

INCONEL Retort Racks



All-Inconel vertical fixture for carburizing small parts. Used in the Stanwood Inconel retort shown above.

INCONEL Furnace Trays —built by STANWOOD



Heavy-duty, grid-type tray for use in continuous furnaces. Guide rails on bottom keep trays in alignment. These trays can be double decked.

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No metal will stand up forever in high temperatures.

But you can plan for *maximum life* . . . by specifying *Inconel* equipment, such as that made by Stanwood.

Inconel is strong. It never rusts. It resists corrosion. It does not scale away through oxidation. It is not embrittled by hardening media.

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As more and more operators switch to Inconel, more and more service records are broken.

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INCONEL...for long life at high temperatures

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LOOK!

for these features when buying your next pot furnace.

Model P1618—16" dia., 18" deep

Double flange pot

Double flange supporting ring

Double flange top ring

Extra pot thickness at liquid level

Element — one continuous helix extra heavy rod

Positive element support in recessed refractory wall

Lining 12¾ inches

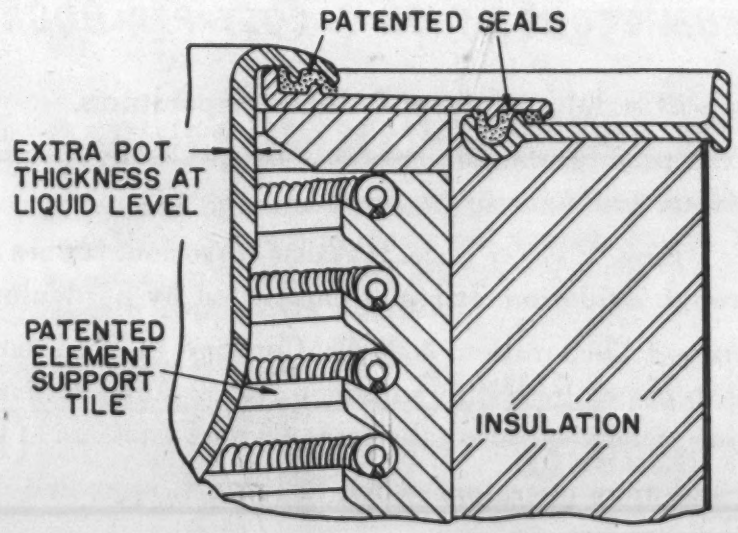
Two point heat control

Time clock starting

Easily operated insulated top covers

For Use with

LEAD – SALT – CYANIDE



American Electric Furnace Company

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Industrial Furnaces for All Purposes

Both fused-salt methods have been successfully used on an industrial scale. The fused-nitrate method was found particularly suitable where good adhesion is essential; where appearance is of greater importance, the fused-chloride dipping method has proved satisfactory. Both methods have been used for tinning small cast iron components in order to facilitate subsequent assembly by soldering or sweating.

On the whole, the nitrate process is preferred for tinning cast iron by dipping and the chloride process for tinning by wiping, but the chloride method is satisfactory for dip-tinning when castings are sound and well cleaned mechanically. Either can be used for coating cast iron with tin-lead alloys by hot dipping. (R. A. Cresswell. Preprint, *Iron & Steel Inst.*, Feb. 1946.)

Honing Techniques

Condensed from "Western Metals"

It is the objective of this article to show how new developments in the honing process provide reproducibility in production processing, as related to the final forming, sizing, and finishing of cylinder bores. Modern honing, which can now remove as much ferrous metal as finish boring or grinding, in many cases in shorter time, offers not only new cost economies but also increased quality control.

In all our surveys we find that design engineering consistently regards geometric accuracy as the first and most important requirement in mechanical efficiency. Without it all other benefits of controlled size, surface quality and careful assembly are of little value.

With modern honing, reproducible, uniform accuracy in most applications for bores above 4 in. in dia. is held within 0.0005 to 0.001 in. for roundness and straightness; in bores from 4 in. dia., within 0.0003 to 0.0005 in., and in bores below 1-in. dia., it is usually well within 0.0003 and in some particular jobs as low as 0.00005 in.

The new size controls used in honing are either of mechanical or fluid pressure types. In the mechanical type size control, the abrasive members in the honing tool are mounted in a plastic shell that serves as a stoneholder. An extended, plastic end tab at each end of the stone, while wearing away as the stone wears down, is allowed to enter a precision sizing ring at the end of each stroke. Then, when the stones have expanded to the desired bore sizing ring size, frictional resistance of the tabs on the sizing ring turn the ring, tripping a micro switch, which stops the honing operation. Fluid pressure type size control is based on the Solex principle of metering the back-pressure on a fluid escaping from a number of orifices in the honing tool body.

Modern honing now removes from 25 to 30 times as much metal as was formerly

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1. Hinged panel for accessibility.
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3. High-torque motor for ruggedness.
4. Totally enclosed relays and galvanometer.
5. Enclosed tarnish-resistant slide-wire.
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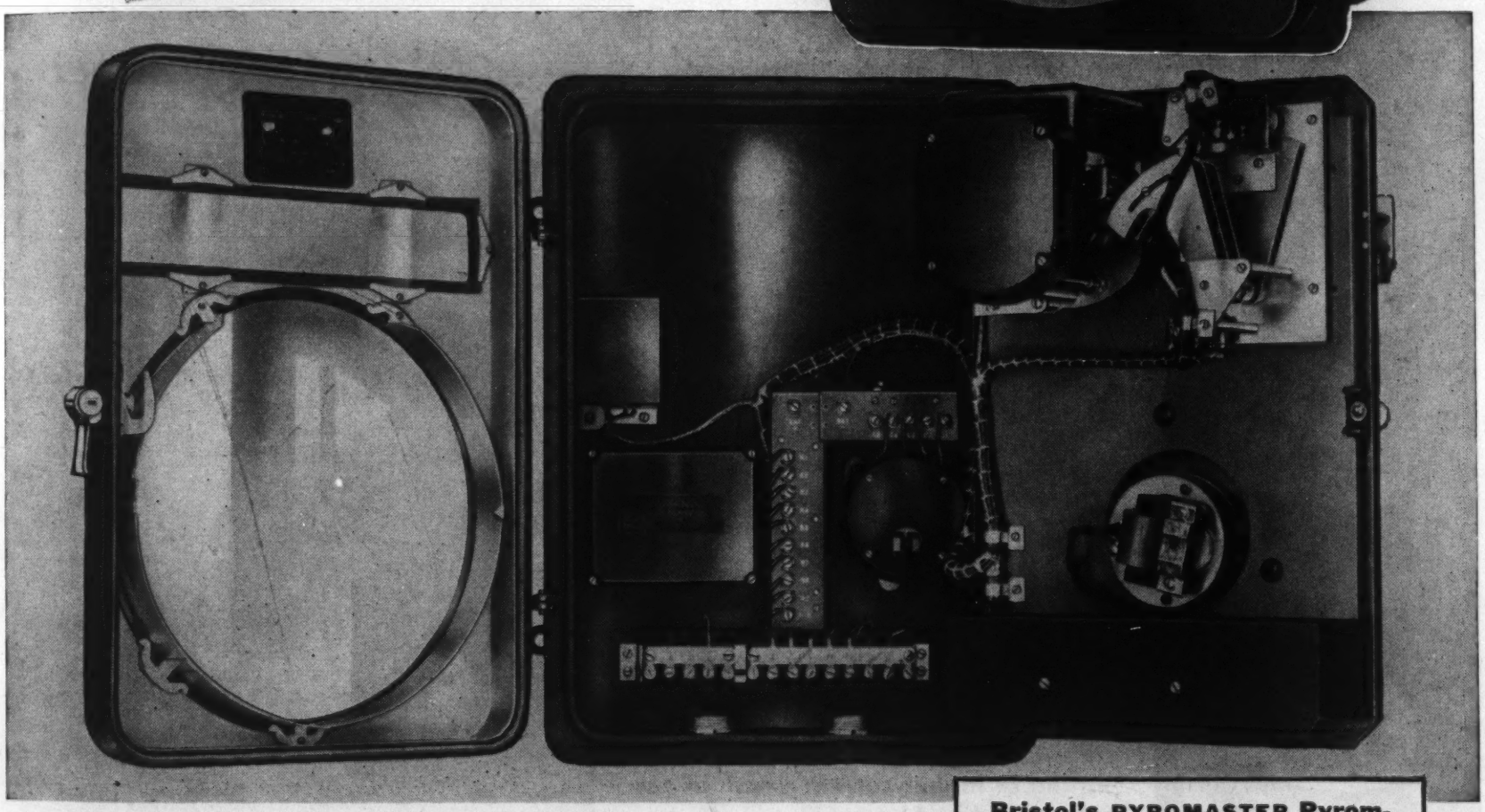

Pyromaster Pyrometer Electric-Type Controller, door open and panel swung out

ALL PARTS ACCESSIBLE: All parts of the Pyromaster are accessible even when the instrument is in full operation. The dial and recording mechanisms are mounted on the front of a hinged reinforced steel panel, which can be swung out of the case as shown above. The slide wire and potentiometer mechanism and, in the case of controllers, the control mechanism are mounted on the back of the panel. Each part or unit can be serviced in place or removed without disturbing any other part.

Complete facts in Bulletin P1200. Address 162 Bristol Road

Bristol's PYROMASTER Pyrometers are available in the following types of instruments for temperatures up to 3600° F.

Electric-Type Controllers, including Proportioning and Proportional Current-Input Control
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METEX ACID ADDITIVE — An individually formulated wetting agent to increase efficiency for fast, positive pickling. Reduces acid concentration required — aids coverage and rinsing when used with IRIDITE and CRONAK solutions.

ROCHELTEX — A new copper addition agent accelerates and improves Cyanide Copper Plating to guarantee brighter, more uniform, copper deposits. Permits plating at higher current densities for both racked and barrel plated articles.

ANODEX — Special variations of Anodex compounds have been individually formulated for specific cleaning application of ferrous and copper buffed metal *with reverse current.*

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practicable, and in some applications it can do this much work up to six or eight times as fast as was formerly possible. Heavier, faster stock removal in hone abrading has been accomplished by two developments: additive treatments of bonding material, and multiple progressive honing using two-and-three spindle machines, equipped with rotating, indexing fixtures. Additive treatments have also greatly increased the life of the honing stones.

It is the function of modern honing techniques to provide any kind of surface finish and bore wall quality that may be desired, or required by conditions of functional operation. This will include controlled surface roughness, such as the "lay" of the cutting mark pattern.

Controllable variations in surface roughness and direction of finish marks serve the function of minimizing wear, preventing fatigue failure, dissipating operating and frictional heat, and assuring complete or adequate lubrication under variable conditions of functional operation. (Lawrence S. Martz & Douglas T. Peden. *Western Metals,* Vol. 4, Apr. 1946, pp. 15-18.)

Bright Dipping

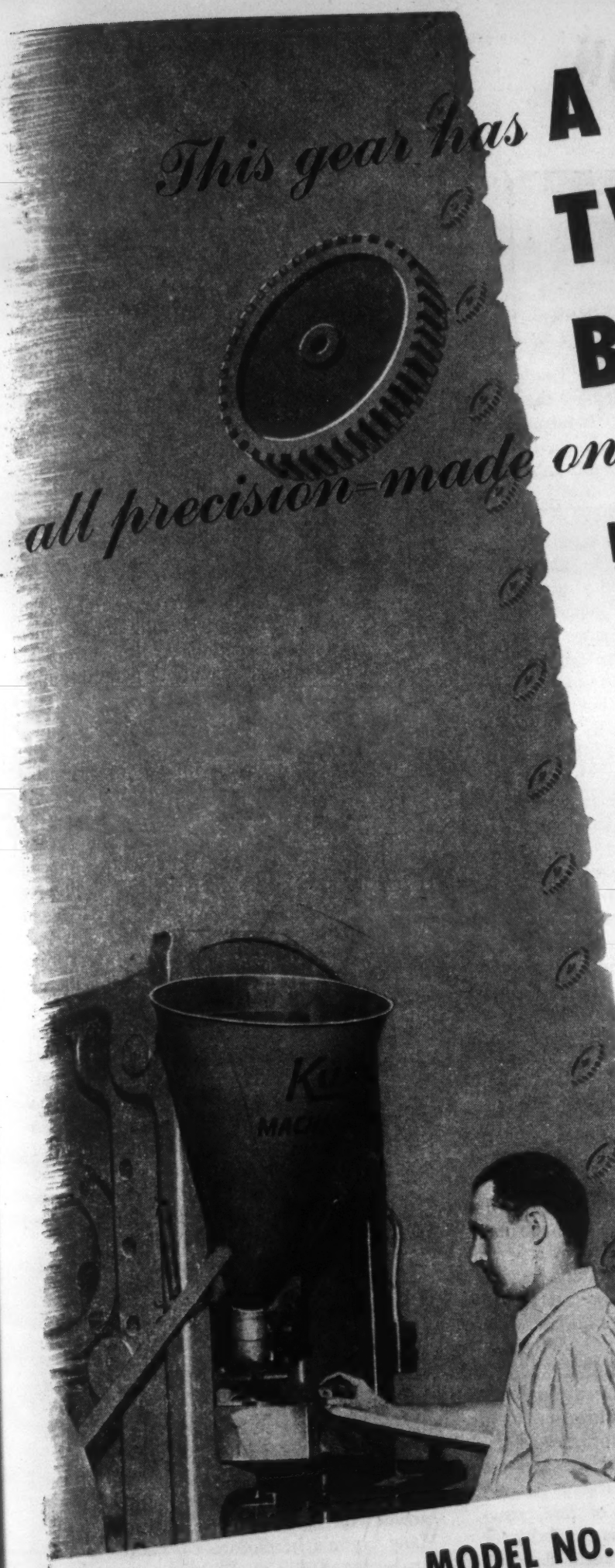
Condensed from "Steel"

The purpose of bright dipping may be to improve the surface appearance, to prepare the surface for subsequent treatment, or to passivate the surface. It is also used to remove a peculiar crystal growth which appears on surfaces that are cadmium plated at very low current densities. It is used primarily on solid copper and brass, and on electroplated coatings of zinc, cadmium, copper and brass.

Copper, bronze and brass are frequently bright dipped in a nitric-sulphuric-hydrochloric acid bath. The hydrochloric acid tends to decrease the attack on the copper and to increase sharply the attack on zinc, while nitric acid functions in the opposite manner. Bright dips for zinc and cadmium plate usually produce the desired brightness on a smooth electroplate in a few seconds.

Ganser proposed an aqueous solution of 0.5 to 1% by volume concentrated nitric acid for cadmium. Unfortunately, this dip accelerates the discoloration of cadmium-plated parts packed closely together. A weaker dip containing 0.25 to 5% by volume concentrated nitric acid has been used very successfully on zinc plate.

Chromic acid dips developed by Dubpernell and Soderberg overcame the tarnishing of closely packed cadmium plated parts and provided considerable passivity. Acidified hydrogen peroxide solutions are being used for bright dipping of both cadmium and zinc plates. The hydrogen peroxide bright dips have the advantage that the reaction products are water and metal salts; however, the passivation afforded is less pronounced than that produced in chromic acid solutions. (Gustaf Soderberg. *Steel,* Vol. 118, May 13, 1946, pp. 109-110.)



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all precision-made on the powerful

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Powdered Metal Products Corporation, Chicago, points with pride to this production achievement.

This small gear had to be held to close tolerances and yet had to be produced in large volume, economically and with utmost precision. PMP solved this problem with powder metallurgy and the Kux Model No. 65 Press. The record stands and speaks for itself. 1,000,000 gears made to close tolerances . . . all identical twins of perfection! Powdered Metal Products Corp. has long been a user of Kux equipment, and thus it was logical for them to depend upon Kux Model No. 65 for a job with such exacting requirements.

Kux equipment can solve your precision production problem too, whether yours be in powder metallurgy, plastics, ceramics or any of the other fields which require high speed, automatic presses.

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Flexible new **MODEL NO. 65**

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- **Parts, maximum diameter . . . 3″**
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TESTING and INSPECTION

Testing methods and equipment for physical and mechanical properties, surface behavior and special characteristics. Radiographic, spectrographic, identification, metallographic, dimensional and surface inspection. Stress analysis and balancing. Specifications, standards, quality control.

Crack Inspection

Condensed from "Engineering Inspection"

Crack inspection has progressed considerably in the past 20 years. In the early days such detection did not depend so much on the eye as the ear. Today the "eyes have it". In the early days defects were supposedly discovered by vibrating or ringing tests. Thus, parts were threaded onto a rope or pole and while hanging were struck with a soft metal rod. In the case of a sound part, the note would be clear and bell like. However, the method would not discover minute cracks, and in complicated designs would give an entirely incorrect result.

One of the older methods that still has much to commend it is the bouncing test. Components are dropped from a certain height upon a hardened steel plate and on the rebound should reach a certain predetermined height.

The acid etch method is extremely useful, especially on nonferrous alloys and stainless steels. Faults that can be discovered are inclusions (metallic and otherwise), cracks, porosity and mechanical defects; also for calculating the depth of carburizing and nitriding. Etching will also reveal the direction of grain and the crystal structure.

Chalk tests have a fine record of detection under certain conditions. Components are immersed in a bath containing paraffin plus a small amount of thin oil which is kept at 160 F (70 C), and allowed to soak for 30 min. They are partly dried, the oil is wiped off and they are dusted evenly with French chalk. Oil still remaining in the defects is pulled to the surface by the chalk, these defects showing as wet lines or blotches.

Probably the most widely used is the electromagnetic method which can be used for magnetic steels; there are two types of such machines: Magnaflux and Electroflux. The former machine is a powerful electromagnet, the poles of which hold the component being examined.

When in operation the flux flows from one pole to the other, passing through the component. Any discontinuities at right angles to the flux flow will form two poles and attract the small iron particles that are suspended in the liquid (largely paraffin oil containing a suspension of fine, powdered iron particles) which is poured over the work-piece when the current is flowing.

In the second electromagnetic method the current is passed through the component and a circumferential field is formed around the part. Here the defects must be longitudinal and this type is for defects of this nature. A recent innovation is the fluorescent flaw detector, components being first soaked in a fluorescent solution, then washed in a blanking off solution. The component is then placed under an ultra violet lamp which fluoresces the defects, the rest remaining dull.

One of the latest methods is supersonic, which has located defects 0.020 in. long at a depth of 40 ft. However, it gives no indication of the size or severity of the defect. (F. W. Giles. *Engineering Inspection*, Vol. 10, Winter 1945, pp. 22-26.)

Microhardness Tester

Condensed from "Steel"

The Eberbach microhardness test method is based upon the microscopic measurement of plastic deformation resulting from the penetration of a diamond pyramid under a specific load. The results are expressed in the same units as the Vickers hardness test.

With the usual technique of preparing metallographic specimens, only a small amount of cold work might be formed on the surface layer, and this light surface effect can be removed by repolishing and reetching. The hardness number will vary with the penetrator load. The decrease in microhardness with increasing loads can be attributed to the work hardening capacity of the metal when indented during the act of hardness penetration.

The primary function of a microhardness tester as a laboratory tool is to record the hardnesses of metallographic constituents or materials which are impossible to obtain by standard methods and to express these values so they are comparable with other hardness figures. A conversion table is given for Eberbach microhardness numbers with four different loads, the superficial Rockwell 30 N and Vickers hardness.

The highly localized determination of hardness made possible by the use of the Eberbach tester opens many new fields of metallurgical control and investigation. Conventional hardness testing is unsatisfactory for sintered parts because of their porosity or duplex structure, but the microhardness tester can measure the hardness of the individual particles.

The testing of carburized, or nitrided layers, electrolytic plating and of hard carbides offers a wide field of application. Many crystals heretofore considered brittle can be tested due to the minuteness of the indentation.

The application of the microhardness tester in measuring hard carbide particles is readily illustrated in the Stellite alloys. As-cast Stellite No. 1, for example, had a hardness of 905 for the eutectic background and 1610 for the extremely hard complex carbides. The Eberbach tester may also be used on non-metallic materials, such as enamel coatings and a phenol-resin plastic used as a corrosion resistant coating. (Howard E. Bernhardt. *Steel*, Vol. 118, Feb. 25, 1946, pp. 92-100, 140.)

New Oakite Surface Treatment

Assures Low-Cost Way to

ANCHOR PAINT to ALUMINUM

PAINT, enamel, lacquer or other organic finish applied for decorative or protective purposes to parts fabricated from aluminum and its alloys stand a better chance of gripping tenaciously if the surface to which such finish is applied is FIRST properly prepared.

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To apply, first give the parts a preliminary cleaning. Then treat surfaces with Oakite Compound No. 36 by using automatic washing machine, dip tank method or a hand-wiping technique. The method you use depends upon the size and shape of the parts to be treated, the volume of production, and the equipment available. For FREE Special Service Report giving details, please write on your company letterhead. No obligation.

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BOOK REVIEWS

Corrosion Symposium

CORROSION OF METALS. *By C. W. Borgmann, C. P. Larrabee, W. O. Binder, H. L. Burghoff & E. H. Dix, Jr. Published by American Society for Metals, Cleveland, 1946. Fabrikoid, 6¼ x 9¼ in., 181 pages. Price $3.00.*

The subject matter of this excellent and informative volume was originally prepared for a series of lectures on corrosion delivered before the Twenty-Seventh National Metals Congress in Cleveland, February 4-8, 1946. When a subject is well understood, it may be effectively presented with conciseness and simplicity. This is true of each of the five contributions. Unlike some other volumes originating from this source, this one is indexed and each section contains a bibliography.

Each of the contributors is very well qualified in his field, which results in an exceptionally well balanced book covering a wide range of theoretical and practical subject matter.

The major subjects covered are the basic principles of corrosion; the atmospheric corrosion of iron and steel; the corrosion resistance of stainless steels and high nickel alloys; the corrosion of copper alloys; and the corrosion of light metals.

The exposition of basic principles by C. W. Borgman, head of Department of Chemical Engineering and director of the Engineering Experiment Station, University of Colorado, is delightful in that it does full justice to theory and, at the same time, embraces many practical considerations which are well illustrated. This chapter could well have included a discussion of corrosion fatigue which is treated only briefly by one of the other contributors.

The next chapter, by C. P. Larrabee, Carnegie-Illinois Steel Corp., deals with the atmospheric corrosion of irons and low-alloy, high-strength steels, and represents a marked contribution to our corrosion literature.

Mr. W. O. Binder, Union Carbide & Carbon Research Laboratories, contributed the chapter on "Corrosion Resistance of Stainless Steels and High Nickel Alloys." Mr. Binder considers the behavior of these materials in a wide variety of industrial environments in which they have been found useful, and also includes numerous practical precautions. In addition to the stainless steels, nickel, Inconel, and Monel metal, this chapter includes useful information on the Hastelloys.

The chapter by H. L. Burghoff, Chase Brass & Copper Co., on "Copper and Copper Alloys in Corrosive Environments" is also well balanced with respect to theory and practice. There are appropriate and informative discussions of galvanic corrosion, pitting, dezincification, stress corrosion or "season" cracking, and corrosion fatigue.

Dr. E. H. Dix, Jr., assistant director of research, Aluminum Co. of America, appropriately writes the section on the "Corrosion of Light Metals (Aluminum and Magnesium)." Dr. Dix is an accomplished student of corrosion, and this chapter is well worth the attention of those who have contact with the light metals beyond the occasional drying of aluminum "pots and pans."

Dr. Dix's chapter is illustrated by a photograph of a number of experimental hoppers built of aluminum. The caption under this photograph states that these "test coal hoppers proved the superiority of aluminum alloys to resist the action of high sulphur coals and encouraged the building of railroad hopper cars." While this test may demonstrate that aluminum alloys resist the action of high sulphur coals when stored in hoppers, it does not necessarily follow that aluminum is proven superior for use in railroad hopper cars.

The type of corrosion encountered when high sulphur coal is stored over long periods of time is very different from that which results in normal service of railroad hopper cars, these being under load only a fractional part of their service lifetime. Thus, the damaging deterioration which follows when the highly poisonous leachings from high sulphur coal are permitted to concentrate and attack the metal is avoided. That this is true is proven by the fact that the sheets of railroad hopper cars, built of ordinary copper-bearing steel, give a service life of from 12 to 14 years before failure due to corrosion, whereas they would last only a period of months if the cars were used as storage bins for high sulphur coal. The conditions illustrated occur only when coal cars are used uneconomically for storing coal over long periods of time.

—WILLIAM B. BROOKS

Wrought Brass

COLD WORKING OF BRASS (WITH SPECIAL REFERENCE TO CARTRIDGE (70-30) BRASS). *By L. E. Gibbs. Published by the American Society for Metals, Cleveland 13, Ohio, 1946. Cloth, 6 x 9 in., 104 pages. Price $2.00.*

The war engendered a widespread interest in the working of brass for ordnance purposes, and this little volume is the collection of a popular series of articles on that subject that appeared in *Metal Progress*. The liberal use of graphs, illustrations and references make this an interesting reference work.

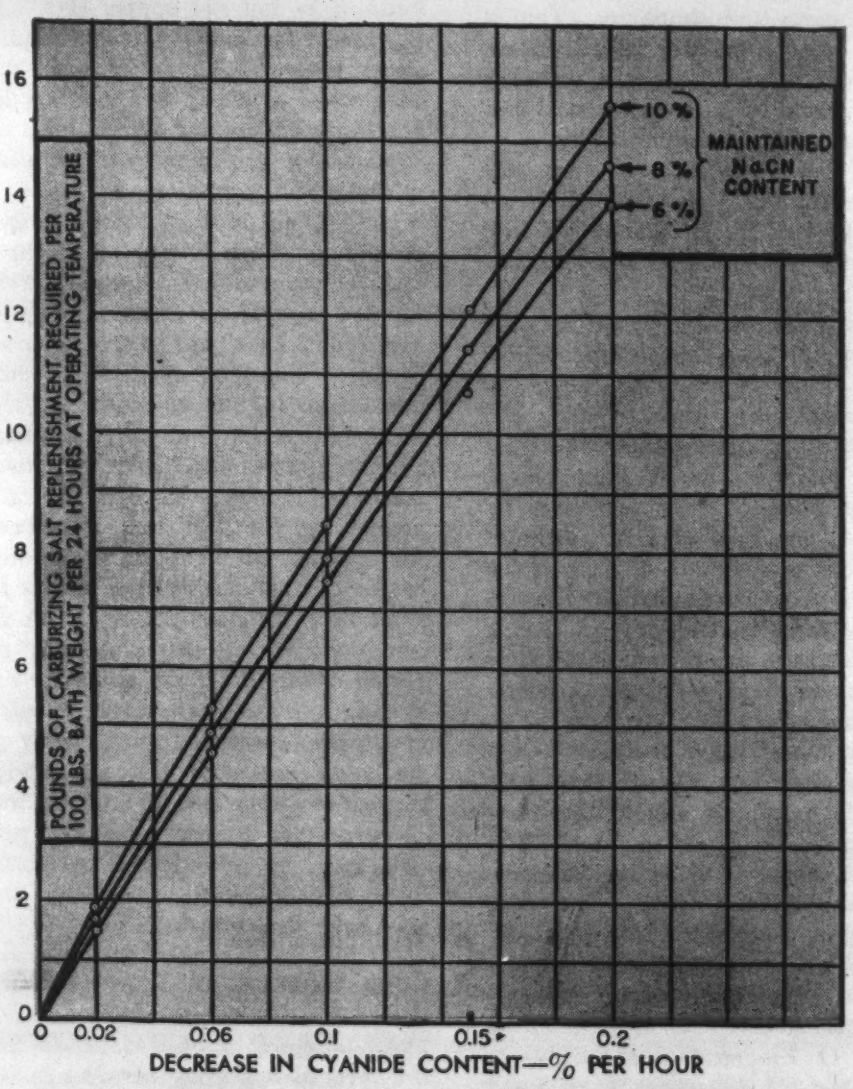
The treatment of this subject is reasonably complete; the author opens with a few remarks about the atomic structure of cartridge brass and then deals successively with cold working and its effect on the material, annealing, the manufacturing process used in the making of cartridges, the effects of chemical composition on the properties of 70-30 brass, "season cracking," and testing.

—ROBERT S. BURPO, JR.

✓HIGH BATH STABILITY
✓RAPID CASE PENETRATION
✓CONSISTENT PERFORMANCE

..mean economy for you with Du Pont

CARBURIZING SALT!



THIS GRAPH shows low replenishment required with molten baths of Du Pont Carburizing Salt.

Molten baths made up with Du Pont Carburizing Salt undergo very slow decomposition. These baths are highly stable even at the maximum operating temperature of 1750° F., using a good graphite cover. This means low replenishments. With treating cycles of 6–8 hours, average replenishment is about 4% of the bath weight per 24 hours' operation.

Most important, with Du Pont Carburizing Salt you rapidly get *deep,* high-carbon, low-nitrogen cases, equivalent to those obtained by pack and gas hardening, at temperatures from 1650° to 1750° F. Carburization begins instantly upon immersion of the work. And when complete, work may be quenched directly from the bath or slowly cooled.

This efficient, economical carburizing medium is but one of many Du Pont products for heat treaters. A Du Pont technical man will be glad to help you select the right materials to meet your specific needs. For more information, just write: E. I. du Pont de Nemours & Co. (Inc.), Electrochemicals Department, Wilmington 98, Delaware.

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FREE MANUAL
ON MOLTEN SALT BATHS

More than 70 pages of practical material on heat treatment, fully illustrated. Ask for your copy.

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CYANIDES and SALTS
for Steel Treating

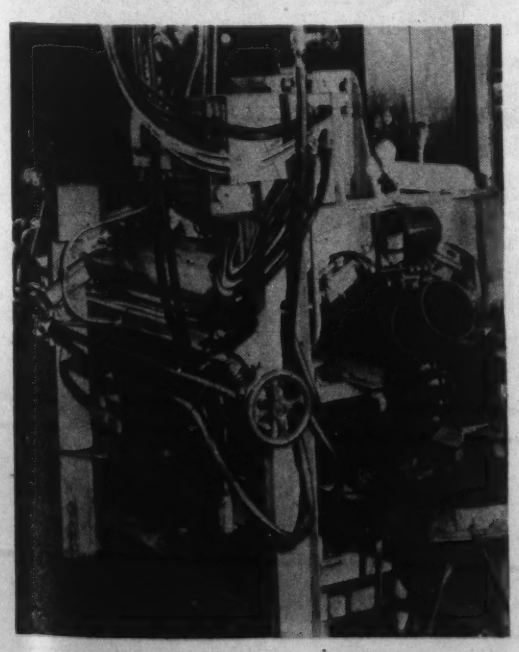
BETTER THINGS FOR BETTER LIVING...THROUGH CHEMISTRY

New Materials and Equipment

Automatic Fixture for Continuous Seam Welding

The *Victory Engineering & Machine Works, Inc.*, 3000 Chouteau, St. Louis 3, Mo., has developed a line of automatic fixtures for continuous seam welding of rounds, squares, and other shapes of tubes and tanks. The old method used in seam welding consisted of clamping the work in a fixture and then moving the welding head along the seam, then breaking the weld, unclamping the work, clamping up the new work and repeating the process. With the use of the automatic fixtures, the welding head remains stationary and the work moves under the welding head.

A variety of shapes and lengths may be processed with the automatic seam welders. The length of any tube being continuously welded at one time is dependent wholly on the methods adopted by the user in bringing the preformed tube to the fixture and the support and removal of the welded tube after leaving the machine.



With a fixture of this kind continuous seam welding of rounds and squares is possible.

Production per hour depends on a few predicted variables and can be estimated with reasonable accuracy. Eliminating labor interruptions and allowing a factor of safety of 25% to cover other contingencies the speed of the weld is primarily dependent on the thickness of the metal being welded—the thicker the gage the slower the weld. In actual production operations, allowing for the above factors which affect average rates, continuous welds of from 60 to 150 in. per min. can be maintained; in one case in particular, a maximum speed of 250 in. per min. has been reached and held for several hours.

In this chain type drive, practically a continuous line contact is made with work instead of the widely spaced point contacts made by the hour-glass type. This allows very short lengths to be run as well as the long ones. The gripping of the line contact is firm and positive, while at the same time it does not leave gripping marks of the fluted drive rolls.

Gas Analyzer and Dew Point Recorder

General Electric Co., Schenectady, N. Y., has announced two instruments for use in determining properties of gases. One of these, a thermal gas analyzer, continuously records or indicates the concentration of one component of mixed gases whose characteristics can be detected by the thermal-conductivity principle. It can detect impurities in hydrogen, carbon dioxide, sulphur dioxide, or any one of many organic vapors, provided the impurity has a different thermal-conductivity from that of the gas being analyzed.

In order to adapt the analyzer to varied applications, a different reference gas can be obtained for each application. A change of the instrument scale and a new cell block, which contains the reference gas, permits an analyzer designed for one atmosphere to be applied to one that is radically different.

Gas analysis is registered on any standard indicating or recording instrument, which can be equipped with contacts for closing an alarm circuit when the concentration reaches a preset maximum or minimum value. In addition, these contacts can be used to control circuits for valves or motors in order to maintain the gas concentration within certain limits.

The other announced instrument is a dewpoint recorder that can determine automatically and continuously the amount of moisture in a gas. The new instrument is designed for applications where the moisture content of atmospheres and gases must be measured or controlled, such as in checking furnace atmospheres, testing city gas, or determining the humidity of gases used in factory production processes.

The new dewpoint recorder is a combination of heater, refrigerator, mirror and gas chamber. The test gas enters the gas chamber and comes in contact with a metal mirror. The refrigerator and heater cool or heat the mirror until a temperature is attained at which moisture in the gas forms dew on the mirror.

A photoelectric eye watches the mirror, and the mirror temperature is recorded on a graph or chart the moment dew forms. Working in co-ordination, the refrigerator and heater hold this dewpoint temperature within a tolerance of two degrees so that a continuous reading on the chart is achieved. The dewpoint temperature that is recorded can then be converted into the moisture content of the gas if desired.

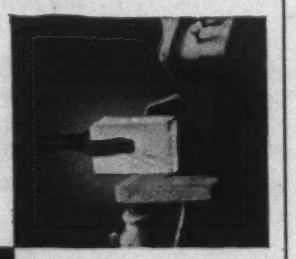
The recorder can be arranged so that it will flash or sound a warning when moisture in the gas reaches too high or too low a level, or control other equipment which will dehumidify or add moisture to the gas. The new instrument is designed for operation at atmospheric pressure over a dewpoint range from ambient to –90 F.

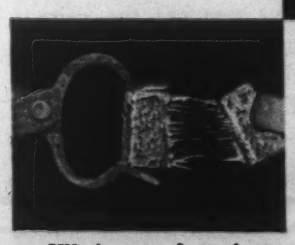
SEND FOR this Brickseal coated BRICK

Brickseal penetrates the pores and joints of firebrick and forms a highly glazed ceramic coating many times harder than the brick.

Tough and semi-plastic under heat, it prevents cracking and spalling regardless of temperature change—heat the sample and douse in cold water any number of times.

Brickseal resists abrasion. Force the sample brick, either hot or cold, against an emery wheel and see the difference on the coated and uncoated sides.





Brickseal is a superior mortar for fire walls. Try to pull the sample bricks apart after they are heated to 2200°.

Write today for a free sample. No obligation, of course.

Brickseal

REFRACTORY COATING

5800 So. Hoover Street, Los Angeles, Calif.
1029 Clinton Street, Hoboken, New Jersey

Measuring, Checking and Inspection Devices

In recent months a number of handy devices for dimensional inspection and checking tools and layouts have been put on the market. A few of them are briefly described below.

Micrometer—The *Sapphire Products Div., Elgin National Watch Co.,* Elgin, Ill., are producing a new sapphire tipped outside micrometer. This micrometer, anvil and spindle of which are tipped with sapphire, is available in 1-in. to 6-in. sizes, English and metric styles. Accuracy is guaranteed within 0.0001 in.

Lead Comparators—A new line of production lead comparators for use in gear production shops has been introduced by

Here is shown one of the lead comparators being used on a gear.

Michigan Tool Co., 7171 E. McNichols Rd., Detroit. Known as Models 1200 and 1200A, the comparators are designed for use on the production floor alongside gear cutting and shaving machines. The machines may be used as an aid in setting up gear cutting and finishing machines, to check gears after processing, and to determine lead compensation for "unwinding" of gears during heat-treat.

The machines are applicable to both external and internal gears as well as worms. To change the machine over for checking gears of different leads, the master lead can be changed to one having a corresponding lead. Different gears of the same lead may be checked by the use of interchangeable mandrels.

The Model 1200 will check helices (up to 45 deg.) at several points around the periphery of internal or external helical gears. For larger helices and to check the leads on worms, Model 1200-A may be used. Both comparators will handle work with a maximum swing of 10 in.

To check a lead, the gear or worm to be checked is mounted on the mandrel and the indicator assembly adjusted normal to the helix angle of the gear, the contact point brought to bear against the tooth surface. The handwheel is rotated so that the tooth surface moves past the indicator, which is graduated in increments of 0.001 in. Accuracy of curve-shaving as well as lead may be checked in this manner.

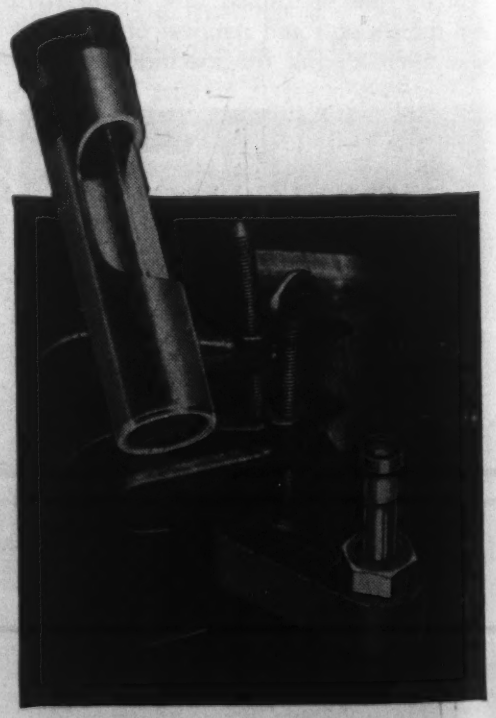
Dial Indicator for File Inspection—The *Federal Products Corp.,* 1144 Eddy St., Providence, R. I., has adapted their regular model dial indicator as an integral part of a gage specially designed for precise dimensional inspection of files.

The gage, which checks the width of the file, ensures uniformity in this dimension. The operator can see on the indicator dial whether the width of the file is within tolerance or not, and if the dimension should be outside of tolerance, how much it is out, plus or minus.

Optical Checking Devices—Two optical tools for the plant and shop have been announced by the *Benton Co.,* 351 South La Brea Ave., Los Angeles 36. One of these is an optical centering tool which locates templates in proper relation to workpieces, centers drill jigs to reference marks or to layouts, and can be used in special setups for measuring between points, work edges or reference lines. On drilling operations the device, known as Opti-Setter, is inserted in a drill jig, which is adjusted until the crosslines in the instrument coincide with any desired layout mark on the workpiece.

The Opti-Setter consists of an aluminum barrel of precision diameter and convenient length in which an eyepiece and reticle are mounted on the upper and lower ends, respectively. The reticle consists of a disc of ground and polished optical glass which is scribed with two fine, interrupted crosslines centered to the barrel diameter. The crosslines are viewed through a magnifying eyepiece and are illuminated through a large window in the side of the barrel. The window is sealed against entry of dust by clear plastic.

The other optical tool measures rake and clearance angles on all types of cutting tools. Angular measurements on cutting



This optical centering tool is handy for locating templates in relation to work pieces and for centering drill jigs.

tools are taken by holding the tool in contact with a straight edge mounted on its base and aligning precision guide lines in an optical viewer with the cutting edge. Readings are then taken directly from a protractor scale. Both the image of the tool and the protractor are viewed through magnifying lenses for greater accuracy and ease of reading.

The optical unit consists of a reticle mounted in a short aluminum barrel and upon which crosslines are scribed. The base is made in two parts: the lower portion being equipped with a straight edge against which the tool is held. A dovetailed slide in the upper portion enables lateral adjustment of the optical unit and contains a bushing in which the optical assembly is snugly inserted.

The device, known as Opti-Check, verifies correct cutting angles, exact clearance angles and uniform length of cutting lips on all tools up to 1-in. dia. It can be used for checking drills, reamers, counterbores, milling cutters, forming tools, lathe tools, etc.

High Density Alloys

Callite Tungsten Corp., 544 39th St., Union City, N. J., has announced the development of a series of high density alloys. These alloys, to be known as Dense Alloy 112, will be available in three general types. These are: Type P—composition largely tungsten, copper, nickel and small percentages of other alloying ingredients; Type E—composition largely tungsten, cobalt, silver, etc.; Type Y—composition largely tungsten, cobalt, nickel.

These new alloys will find their major application where high strength and high density is of prime importance. For example, they are especially adaptable as balancing weights where space is a prime factor. Because of their machinability, precise balancing can be attained, such as is required in rotors and governors for gyroscopes. Ordinary machining operations, such as milling, shaping, turning, drilling, tapping, etc., present no difficulties.

The high density of these alloys becomes quite apparent by comparison, for example, with lead. Lead has a density of 11.3 gms. per cc., while these new dense alloys are 17.3 gms. per cc.

The alloys are produced by powder metallurgy, and are available in round, square and special shapes. The scope of these alloys is further increased by the fact that they can be brazed or soldered by standard commercial methods. Other advantages result from the self-fluxing properties of the alloy. Under certain conditions larger billets or unusual shapes can be formed from simple forms.

The new silver-molybdenum alloy, called Callinite Type SM, has also been announced recently by the same company. This product is particularly suitable for facing of contact surfaces in switch gear designed to handle heavy currents. It is a high conductivity facing material suitable for applications requiring high current where pitting, sticking or welding of contacts occurs.

● *Lawrence Engineering Service*, 100 Snyder Ave., Peru, Ind., has developed a calculator for calculating proper spindle speeds, for drilling, reaming, milling, turning or grinding operations. The calculator has three diameter scales graduated in inches, millimeters and number and letter drill sizes. These scales enable readings without reference to tables or handbooks. It handles cutting speeeds from 15 to 8,000 f.p.m. (including grinding speeds), diameters from a No. 80 drill (0.0135 in.) to 8 in., and spindle speeds from 7 to 100,000 r.p.m.

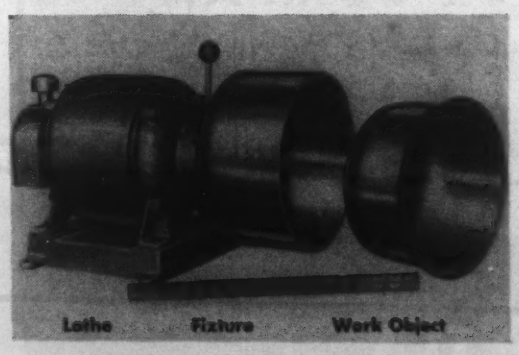
Vacuum Grip Lathe

A new model, heavy duty, vacuum grip speed lathe, introducing a built-in wet vacuum pump that holds work pieces without chuck or collet, has been announced by the *Crozier Machine Tool Co.*, 654 North Prairie Ave., Hawthorne, Calif.

Without the use of piping or glands, the patented built-in pump generates its own vacuum that holds the work when the lathe is in motion, releases the work when the machine is stopped. Starting and stopping of the spindle are accomplished through an ingenious mechanical brake and switch (also patented) that is controlled by a single lever.

A perfect vacuum seal is created by drawing oil from a large reservoir into the pump early in the vacuum cycle. The oil is separated from the exhaust air on the discharge cycle, and being recirculated requires only occasional replenishment.

Adaptable to both small or large work pieces, the vacuum grip lathe holds metal, plastic, rubber, wood or glass. Its uses include lens grinding, utensil polishing, utensil sunraying, disc valve grinding, trimming rubber products, removing flash from plastics products, machining copper discs, and polishing of ash trays and novelties.



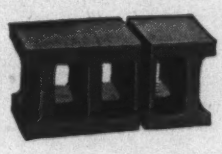
This vacuum grip lathe can be used in a variety of machining and polishing applications.

FASTER CUTTING ...with Clipper Masonry Saws

Your Special Size and Shape Brick or Concrete Block can now be "Tailor-Made" at a moment's notice!

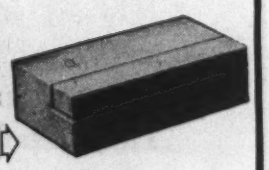
The new Clipper Multiple Cutting Principle makes possible faster cutting of every masonry material regardless of hardness.

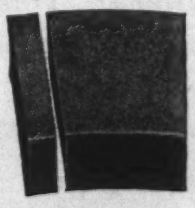
Here are a few typical examples of the speed and accuracy with which concrete products and fire brick can be cut.



This concrete block, converted into a special size, was cut completely in two in 19 seconds.

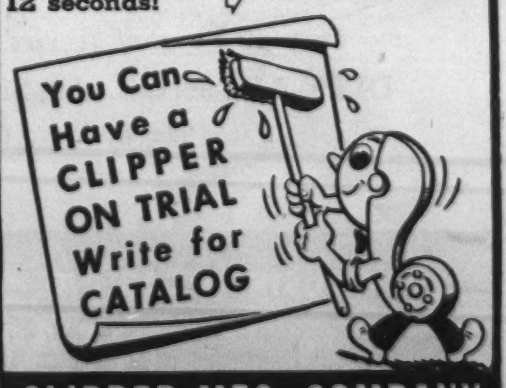
One of the many intricate cuts performed on first quality clay brick for heat treating furnaces —made in 8 sec.





Rotary Kiln Blocks, cut to size for "key" bricks in rotary kilns, require only 10 sec. for completion of cut.

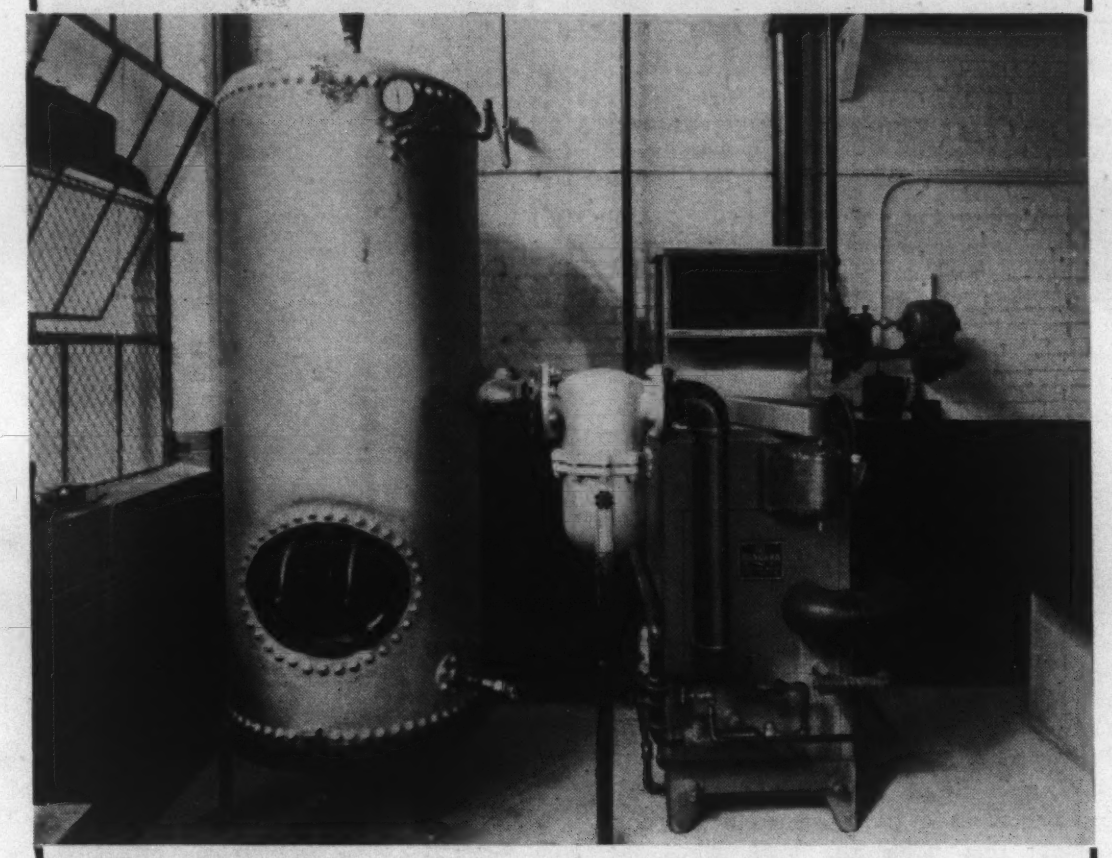
Basic refractories for steel furnaces or cement kilns must be accurately installed. This magnesite brick was cut in 12 seconds!



CLIPPER MFG. COMPANY
4037 Chouteau St. Louis 10, Mo.

NIAGARA *Aero*

AFTER-COOLER ASSURES DRY SANDBLASTING!



Many industrial plants answer the problems of rust in shot blasting and damage from condensed moisture in sandblasting with the NIAGARA *Aero* AFTER-COOLER. They report better than satisfactory results because of delivery of *drier air*. This is in addition to the 95% saving in water costs and constant jacket water temperature advantages made possible by *"Aero"* cooling and the Niagara "Balanced Wet Bulb" control.

If sandblasting free from rust and moisture troubles is one of *your* objectives, be sure to send for NIAGARA bulletins 96 and 98 to prove further the profits you can make by employing the Niagara *Aero* After-Cooler.

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New Metal Cleaners

Metal cleaning compounds are constantly being developed for specific sets of cleaning applications. Here are a group of new metal cleaners that have come to our attention during the last few weeks.

A new self-emulsifying, water-mixable solvent, called Oakite Composition No. 98, for removing light shop dirt and nonpigmented stamping compounds from steel and aluminum work, has been made available by *Oakite Products, Inc.*, 57 Thames St., New York 6. It is for use primarily in pressure-spray washing machines.

The solvent is nontoxic and noninflammable in solution. In use, it has the characteristic of floating the lighter-than-solution soil on the surface of the solution tank. This provides a bulk of clean solution under a thin blanket of floating foam and soil, which may be periodically skimmed or overflowed. This blanket also retards foaming tendencies and prevents material losses through evaporation. Spray nozzles which deliver streams of solution in good volume are preferable to the atomizing type in the machine.

The cleaning compound can be used on steel prior to painting, without rinsing, and because it leaves no strongly alkaline film, it is suitable for the washing of steel and aluminum parts, between operations or before inspection. In two-stage washing machines, it is frequently advisable to put ½ of 1%, by volume, in the rinse tank after a general cleaning of the machine. It is advantageous to age the solution for a minimum of 30 min. before starting the spray washing pumps, in order to reduce foaming tendencies of "green" solution.

Gaybex Corp., Nutley, N. J. has released its emulsifying degreaser, G-BEX D, for general distribution. This product was developed during the war to meet the problems of overseas packaging and steel parts machining as a cleaning and protective agent.

The cleaner is a neutral emulsifying solvent having a minimum flash point of 165 F (ASTM C. O. C.). It is nonirritating to the skin and is considered noncorrosive to all standard construction metals. It will not strip paint or lacquer, and may be used for light or heavy duty degreasing by spray, brush or soak application followed by water rinse.

Steel bearings and parts can be handled without fingerprinting after being cleaned and water rinsed. The slight protective film remaining after the wash is said to persist for several months.

The production of two new metal cleaning products are announced by the *Pennsylvania Salt Manufacturing Co.*, Widener Bldg., Philadelphia. The one, designated as A-22, is a general purpose soak tank cleaner for use on all aluminum alloys. Most common applications are cleaning aluminum before anodizing, chromodizing, phosphatizing and other pre-painting treatment and before deoxidizing and subsequent spot welding.

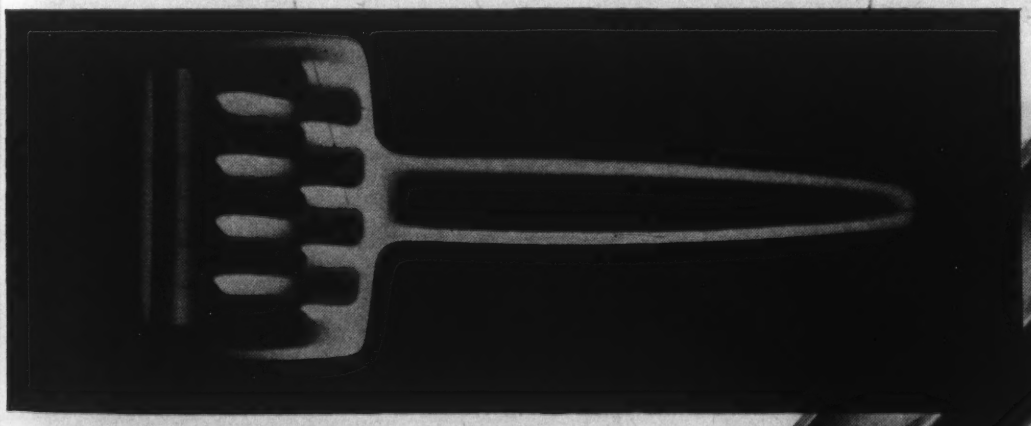
The other, PM-95, is a specially prepared cleaning and descaling compound containing additional agents for surface action and inhibition. Suggested uses are general pickling and metal descaling, especially for difficult-to-remove oxides resulting from heat treating or annealing.

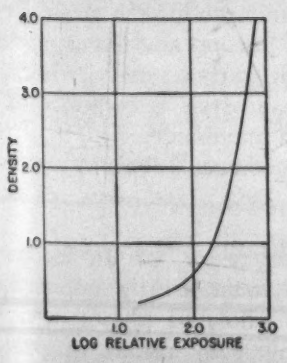
Q. Which x-ray film for examination of aluminum pilot castings?

A. Kodak's Industrial X-ray Film, Type A

For his examination of this aluminum ice crusher, the radiographer chose Kodak's Industrial X-ray Film, Type A. He knew that Type A had more than adequate speed for economical exposure times, and that its fine grain and high contrast would give him the excellent detail he needed.

For general use in jobbing foundries where light alloy castings are produced . . . Kodak's Type A, with or without lead foil screens, will give results which meet the requirements of sound radiographic practice.





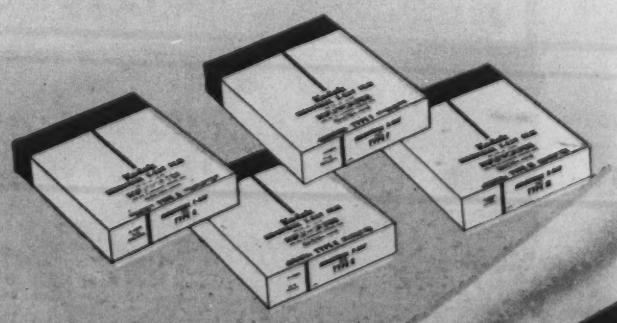
Characteristic Curve, Kodak Industrial X-ray Film, Type A: with direct x-ray exposure or with metallic screens. Development: 8 minutes, at 68° F., in Kodak Rapid X-ray Developer, or Kodak Liquid X-ray Developer and Replenisher.

In addition to Type A, Kodak offers these 3 important types of industrial x-ray

Kodak Industrial X-ray Film, Type K . . . primarily for g and x-ray radiography of heavy steel parts, or of lighte at limited voltages where high film speed is needed.

Kodak Industrial X-ray Film, Type F. . . with calcium tu screens—primarily for radiography of heavy steel part fastest possible radiographic procedure.

Kodak Industrial X-ray Film, Type M . . . first choice for inspection of light alloys or, with million-volt radiog of steel and heavy alloy parts.

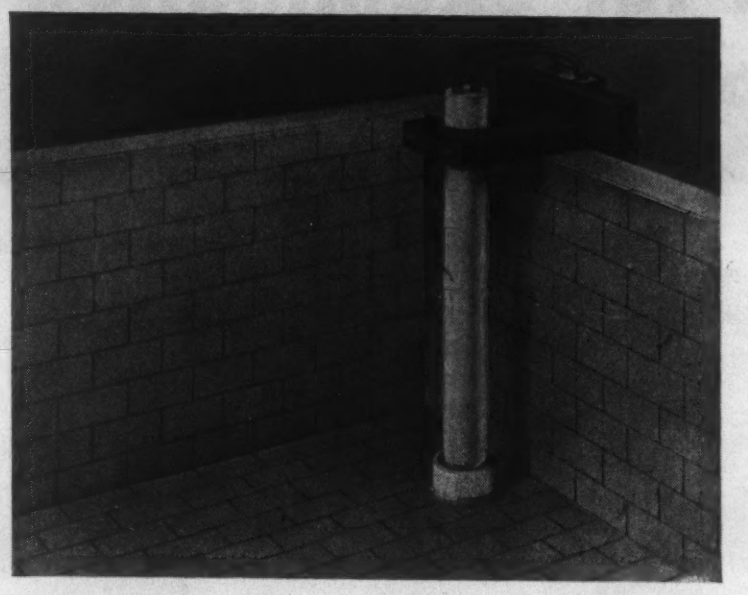


EASTMAN KODAK COMPANY

X-RAY DIVISION, ROCHESTER 4, NEW YORK

Koda

IMMERSION HEATING WITH VITREOSIL (Vitreous Silica) HEATERS



When other methods are unsatisfactory, acid solutions in tanks of any material can safely be heated by Vitreosil electric immersion heaters.

VITREOUS SILICA — VITREOSIL — REG'D TRADE MARK

SEND FOR BULLETIN #2

THE THERMAL SYNDICATE, LTD.
12 EAST 46th STREET, NEW YORK 17, N.Y.

"Falls Brand" Alloys

"FALLS" COPPER SHOT
for Addition to Cast Iron

Promotes the following properties:

Increased tensile strength, transverse strength and Brinnell hardness.

Increased wear resistance— Increased resistance to heat and corrosion.

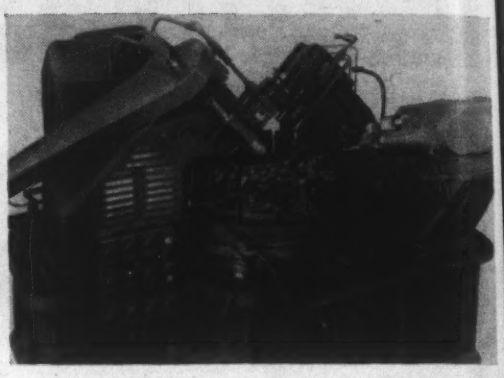
Increased fluidity and sharper castings.

WRITE FOR COMPLETE DETAILS

NIAGARA FALLS SMELTING & REFINING CORPORATION
America's Largest Producers of Alloys
BUFFALO 17, NEW YORK

Machine for Machining Intake Manifolds

A special purpose four-stage machine for the drilling, spotfacing, counterboring and tapping of the vacuum holes in intake manifold, has been completed by *Hydraulic Machinery Inc.*, 12825 Ford Rd., Dearborn, Michigan. The cycle of operation is as follows: (1) Part manually loaded and clamped into position; (2) upon closing safety door, electric contact is made and the machine automatically indexes to position, all heads moving forward and completing



This special purpose machine performs four machining operations on intake manifolds.

the cycle of drilling, spotfacing, counterboring and tapping; (3) part is unloaded. The production rate of the machine is 120 manifolds per hr.

The machine is hydraulically operated and electrically controlled and arranged with safety features, provisions being made to prevent indexing until part is properly clamped in position. All hydraulic power and control valves are mounted in the base with access doors for servicing.

Automatic Atmosphere Generator

The *Lindberg Engineering Co.*, 2444 W. Hubbard St., Chicago, has developed an endothermic atmosphere generator that can furnish atmosphere for a number of furnaces. This new unit produces a clean, dry gas for hardening, brazing and sintering all medium and high carbon steels without carburization. Gas analysis is carbon dioxide, 0.0%; carbon monoxide, 21.0%; hydrogen, 40.0%; methane, 1.0%; nitrogen, 38.0%; oxygen, 0.0%; and dew point, −20 F.

Like an air compressor, or an electric generator, the equipment is fully automatic. After lighting the pilot, all phases of operation are controlled by means of push buttons. The generator requires no charcoal, and does not have to be burned out periodically to remove soot.

The unit operates by city gas, natural gas, propane, or butane for both atmosphere and heating. A refractory retort permits the use of higher cracking temperatures, thus enabling the unit to produce a cleaner and drier gas.

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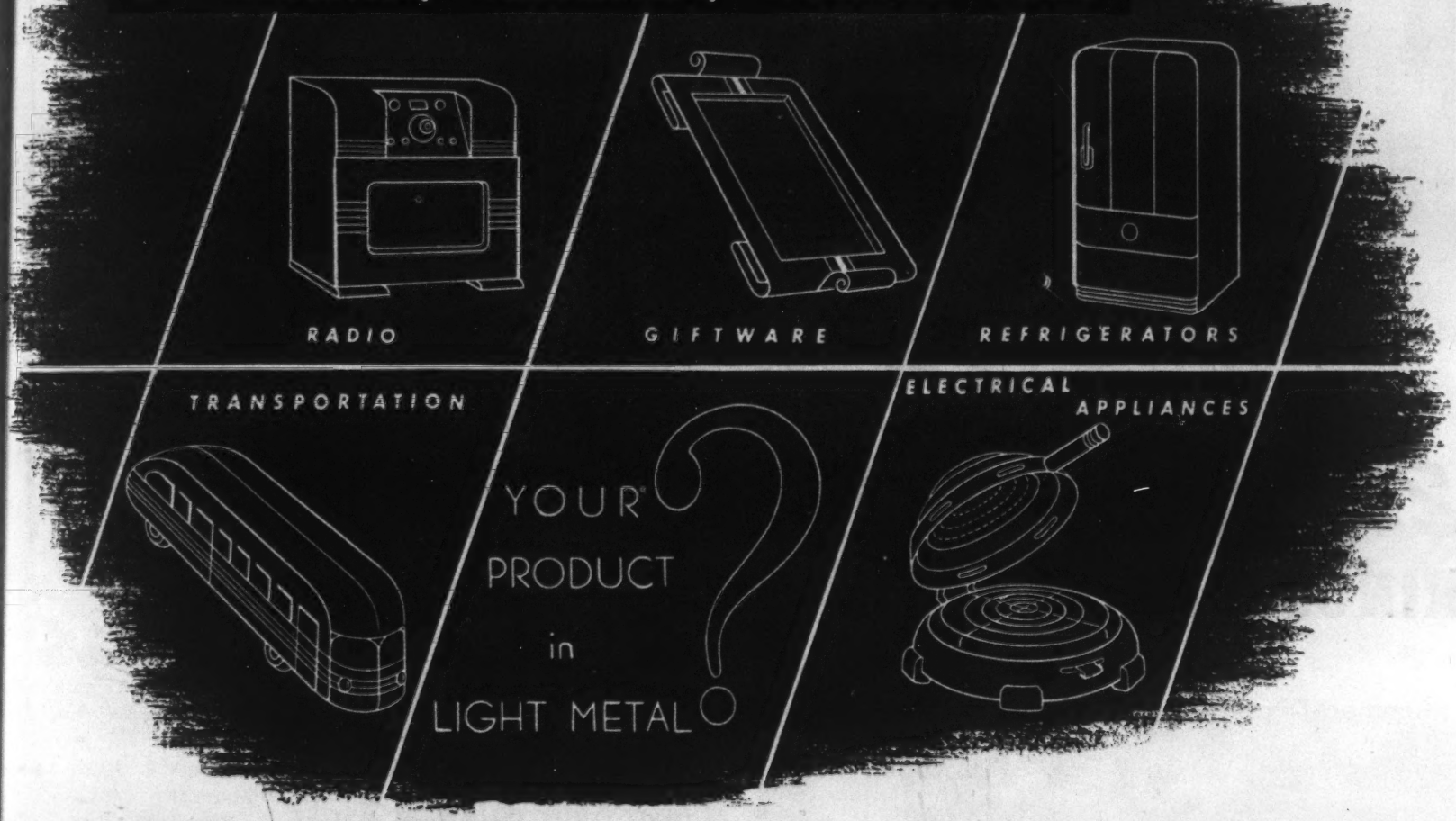
designs, fabricates, assembles
your new or improved product
in ALUMINUM, MAGNESIUM, STAINLESS STEEL



You name it, and let COLGATE work out a design with you. Then let us make it, partly or completely, fabricating and assembling your new or re-designed product from Aluminum, Magnesium, or Stainless Steel to give it these sales creating features—*lighter weight, added beauty, increased strength and durability, improved product performance, lower fabricating costs, reduced shipping weight.*

COLGATE'S "Engineered Service" provides helpful and cooperative preliminary conferences that save you time and expense *before* designs have been started, also after blueprints have been prepared. This unique COLGATE service helps develop your new product ideas, improves old products, explores the possibility of substituting light metals for other materials, and plans short-cuts for fast, economical production and the assembling of parts.

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Let COLGATE help get your product to market faster, better, more economically, and also solve your reconversion and production problems. Learn how "Engineered Service" can give your product the sales advantages of the light metals. Consult with COLGATE *now!* — no obligation, complete confidence assured.

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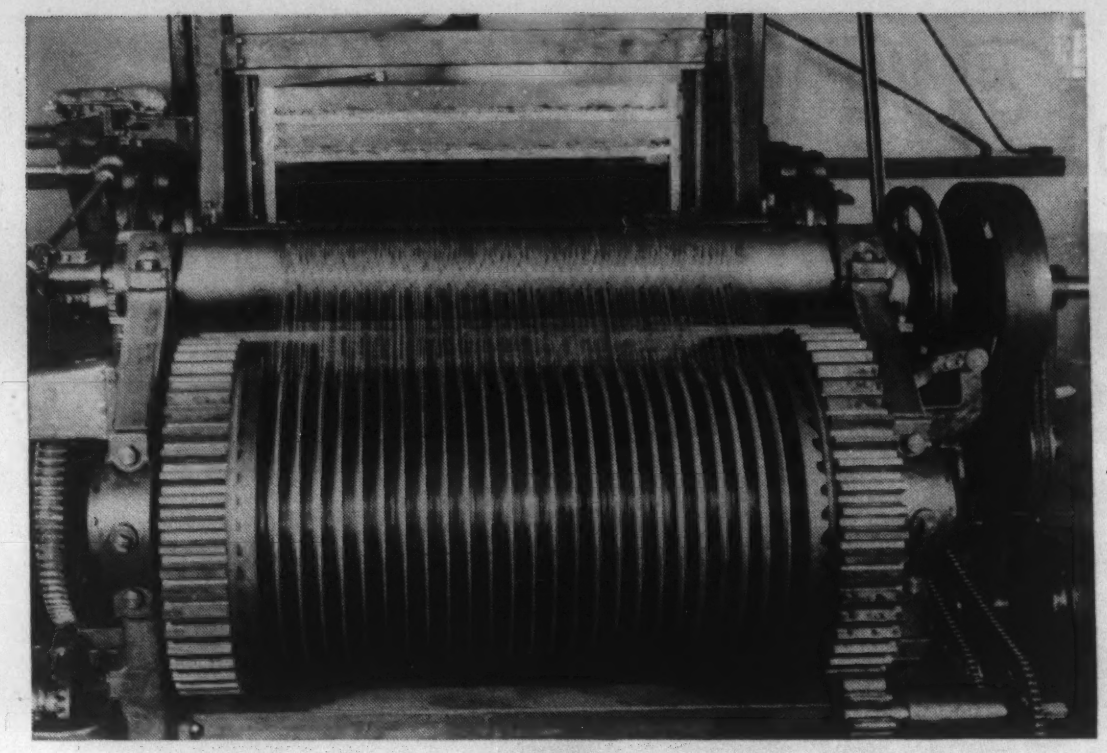
LIGHT METAL PRODUCTS DIVISION



25—COUNT 'EM—STEEL SPACING RINGS BENT BY KING!

Mummert-Dixon Company of Hanover, Pennsylvania, makes a Heavy Duty Wire Loom. The business part of it is the warp drum shown in the photo above. On the warp drum are 25 steel spacing rings and these are furnished Mummert-Dixon as rough welded flanges by King Fifth Wheel. Mummert-Dixon shrinks on the rings and accurately machines them. Here's another example of King versatility, service, engineering experience put to work for its client.

MANY THANKS TO MUMMERT-DIXON COMPANY FOR THE INFORMATION AND PHOTOGRAPH. WE'RE PROUD TO WORK WITH AND FOR YOU.

KING *Fifth Wheel* COMPANY

2925 N. Second Street, Philadelphia 33, Pa.

Extension Type Portable Pyrometer

The *Wheelco Instruments Co.*, 847 W. Harrison St., Chicago, announces a new extension type portable pyrometer. This unit has been designed to permit a choice of plug-in angle extensions where a number of applications necessitate a universal instrument for measuring and checking temperatures requiring the use of different kinds of thermocouples.

A high resistance meter movement consists of baked, processed coils, supported by two lapped pivots resting in two polished sapphire resilient jewels. An Alnico #5 magnet, resistant to shock, heat, vibration and stray fields, provides increased ruggedness without a loss of sensitivity. Automatic compensation is a standard feature.

A calibrated Briguet spiral automatically corrects readings for variations in cold junction temperature. To protect the meter when instrument is not in use, a shunt lever is provided.

Plug-in extensions are available in either straight, 45-deg. or 90-deg. angle types. Adapters permit the choice of material and calibration of thermocouples. Dual iron constantan scales are calibrated from 0 to 600 F or 0 to 1000 F, and dual chromel-alumel scales are calibrated from 0 to 1600 F or 0 to 2500 F.

● Copper, brass or plastic vise jaw caps, in several different sizes and ranging from 3 in. to 6 in., have been announced by *Gregory Tool & Manufacturing Co.*, 5300 Tireman Ave., Detroit 4. The metal caps are made from mill bars to assure smooth soft surfaces without any hard spots, to grip all classes of finely finished work. Plastic caps are recommended for finely finished soft metal surfaces.

Dielectric Heating Unit for Plastic Molding

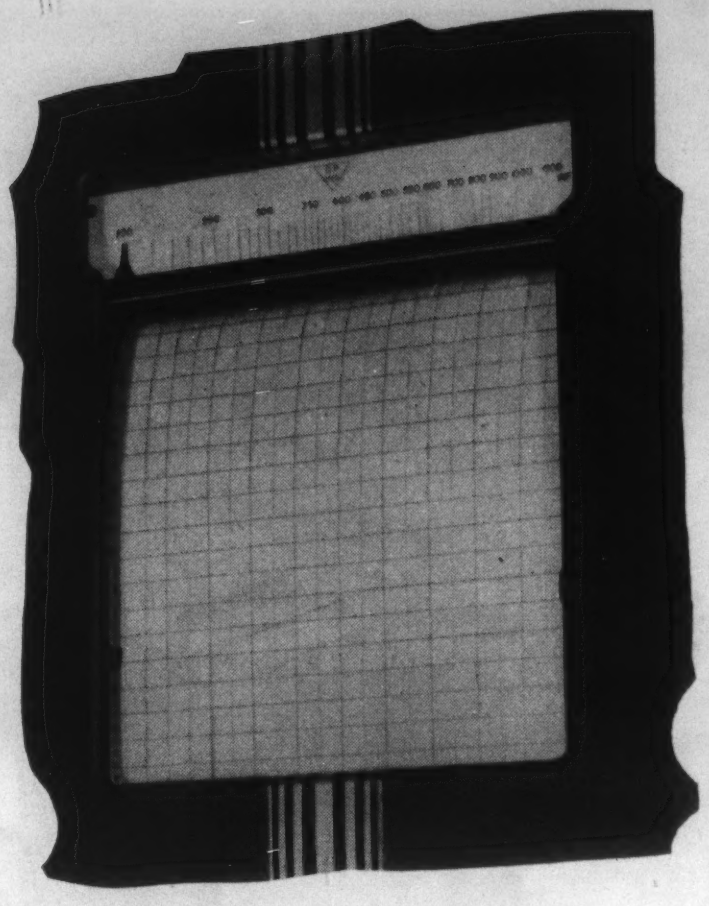
A new portable high frequency dielectric heating unit has been designed for the plastics molding industry by the *Thermex Div.* of The *Girdler Corp.*, Louisville, Ky. It has an output of 1-kw., and will raise the temperature of approximately 1 lb. of average general purpose material 170 F in one min.

The heavy gage steel cabinet is 16¼ in. wide, 27¼ in. deep and 52¾ in. high.

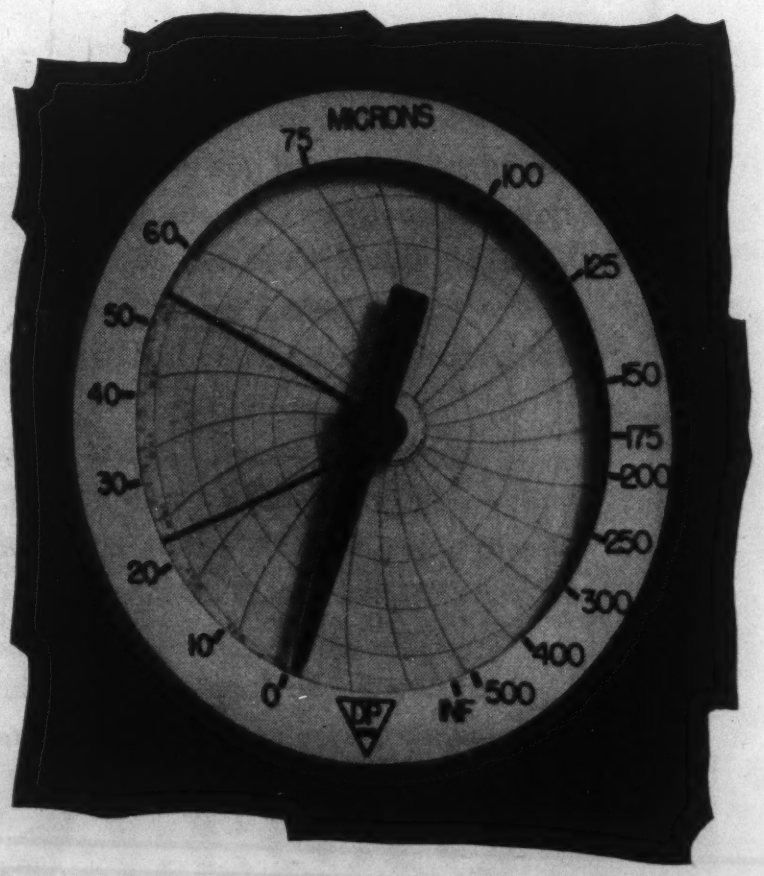
The 10¼-in. by 13-in. preform tray, which serves as the bottom electrode, is an aluminum plate; the standard upper electrode is 7½-in. by 7½-in. stainless steel wire mesh. Spacing between the electrodes is adjustable from ½ in. to 3⅜ in.

The drawer accepts preforms up to 2½ in. in thickness. Closing the drawer all of the way turns on the high frequency energy, which cuts off when the predetermined heating cycle is completed.

D.P.I. RECORDING GAUGES GIVE YOU COMPLETE AUTOMATIC CONTROL OF HIGH-VACUUM PRODUCTION. THEY ARE DEPENDABLE...



Overseers of Emptiness



THE pressure range in which your high-vacuum equipment operates determines the gauge and recording meter (potentiometer) that you should use. For example, recording pressures in the range from 0.001-mm. to 1mm. calls for the D.P.I. Pirani Gauge and potentiometer... pressures from 0.00002mm. to 0.025 require the Philips Gauge—and, for the lower pressures down to 0.0000001, the Ionization Gauge is recommended. Recorders of either the "strip" or "clock" type can be provided. Both types are illustrated on this page. For complete, final control, contacts can be installed to operate alarms, switches, valves, and other devices that individual needs may indicate.

OUR INSTRUMENT ENGINEERS WILL BE GLAD TO HELP YOU SELECT THE RECORDER BEST SUITED TO YOUR PURPOSE. WRITE—

Vacuum Equipment Division

DISTILLATION PRODUCTS, INC.

Rochester 13, N. Y.

Check ATMOSPHERE—PRODUCER Efficiency

INSTANTLY!
ACCURATELY!
EASILY!

The Engelhard Flualyzer is a highly sensitive instrument particularly adapted to determining the carbon dioxide content of the generated gas in either oil or gas fired atmosphere type heat treating furnaces. Extremely accurate results are obtained by combination of the time-proven Wheatstone Bridge circuit for the analysis of CO_2 with the Engelhard Thermocouple circuit for the determination of temperature.

Compact and completely self-contained, the Flualyzer is light-weight, portable, easy to handle. Readings are taken directly from a double range indicator calibrated from 0 to 20% of CO_2 and 0 to 1000° F.

A trial will convince you that this modern instrument provides maximum convenience and reliability as a furnace atmosphere test unit.

Write today for details and specific application data.

CHARLES ENGELHARD, INCORPORATED
90 CHESTNUT ST., NEWARK, NEW JERSEY

Dial Thermometer

A new stainless steel dial thermometer designed for all industries is announced by *W. C. Dillon & Co., Inc.*, 4510 W. Harrison St., Chicago 44. The instrument can be used for temperatures up to 750 F with an accuracy of 1%.

The thermometer is all metal welded construction. It has a stainless steel stem and mounting nut. The pointer is fixed to a stainless steel shaft, and the shaft directly to the coil. The dial is made of anodized aluminum and is heat resistant.

Either a 5-in. or 9-in. long stem may be used. When used in liquid the stem should be immersed 2 in.; in gas the stem should be immersed 4 in.

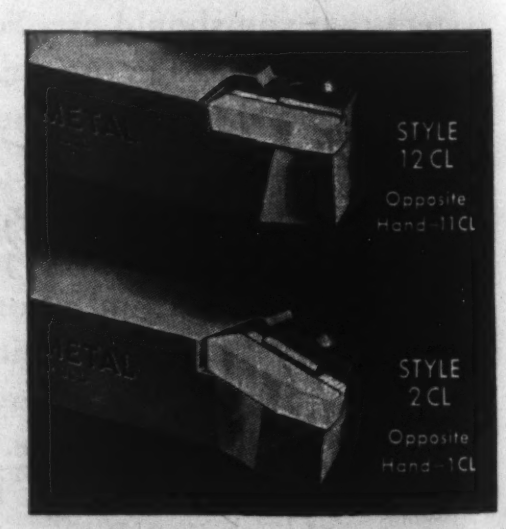
Tungsten Carbide Tools

Kennametal Inc., Latrobe, Pa., has recently announced several new developments. Among these are two new types of tools having clamped-on, advanceable tungsten carbide tips. One of the types (1CL and 2CL) has offset shanks and the other type (11CL and 12CL) has straight shanks.

These tools are said to have greater durability and more consistent performance because of the thermally strain-free assembly. Dull tips can be advanced and resharpened. Tips of different grades can be interchanged on the same shank, thus adapting the tool for machining different types of metals.

The same company is now producing a line of solid tungsten carbide grooving-tool blades. These blades, because of their rigidity, minimizes "weaving" which is, apparently, a major cause of rapid tool wear on grooving jobs.

Kennametal has also announced the production of a disc file for use on light alloys,



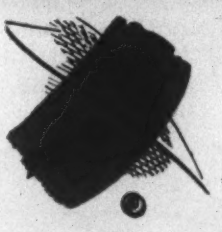
The tool tips are clamped on the shank as shown here.

die casting, and plastics. The tool is designed to facilitate the facing of rough castings, and removing of unwanted projections, such as flash or draft, gates and risers.

It consists of double-cut segments of solid tungsten carbide, dovetail-wedged into a 12-in. dia. steel body which can be supported and driven by any suitable means.

"talk about a versatile metal!

they're using Carboloy on everything from buttons to boiler tubes!"



"Buttoning-Up a Problem in the Button Industry"

"First, take a look at this, my friend. This button manufacturer really had his troubles trying to get a swell finish on suit buttons. He even brought special machines from Germany, but those abrasive buttons gave his tools such a beating they had to be reground each time. Somebody suggested Carboloy, and that's when things started looking up! Why, the finish was so slick it cut the time of the important tumbling operation to practically nothing. And saved plenty in tool wear, too!"

Helping a Pen Maker "Keep Up Appearances"

"—And how about *this.* A pen and pencil manufacturer, in redrawing cupped steel parts to proper size, found that steel dies wouldn't work at all. They picked up badly, caused faulty drawing, and ruined the appearance of the caps. So, the company tried Carboloy—***and what a difference!*** The finish came out ***beautiful***—and they cut tool costs plenty, besides."

Something to Puff About!

"Now, pardon the chest expansion here, but we're downright proud of what Carboloy did for this cigar company. When they were using brass bushings in their final wrapping machines, they had to rebush completely every three months. So, to cut this expense down, they gave Carboloy a whirl. Last time I heard—those same bushings were still in use, after 7 months continuous usage, producing nearly ¾ million units. ***Have a cigar!***"

Carboloy Serves at Sea, Too!

"Funny, but you meet Carboloy in the darnedest places! Get the picture—a ship at sea—the boiler tubes get clogged up with seawater scale. So what do they do? Well, they simply bring up a motor-driven drill equipped with Carboloy-tipped cutter blades, and start boring in. Bites into that tough crust like a hot knife into butter. Works twice as good as previous blades—and a lot faster—and holds true to size longer. And abrasive as that scale is, do those Carboloy-blades live a long time! Get what I mean when I say: ***Carboloy's really a versatile metal!***"

The word "Carboloy" is a registered trademark of Carboloy Company, Inc., sole makers of Carboloy Cemented Carbides.

To Speed Your Ideas Into Metal:

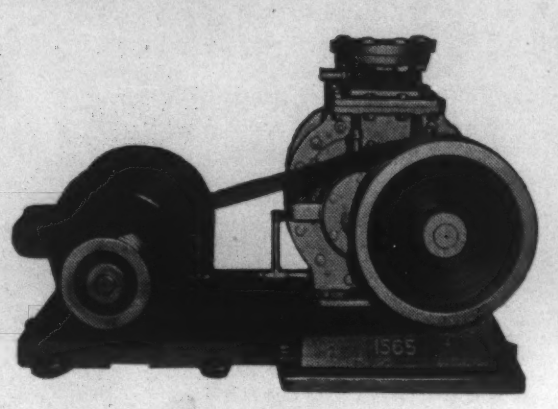
Carboloy can help you, too. Supplied in virtually any shape or size, for use wherever there's wear on product parts or on tools and dies for cutting and forming, you'll find it really does the job! Tell us about your problem, and we'll be glad to advise you (no obligation, of course).

*CARBOLOY
(TRADEMARK) CEMENTED CARBIDE
HARD METAL

11160 E. 8 MILE BLVD. DETROIT 32, MICH.
Detroit 32, Michigan
CHICAGO • CLEVELAND • DETROIT • HOUSTON • LOS ANGELES
MILWAUKEE • NEWARK • PHILADELPHIA • PITTSBURGH • ROCHESTER

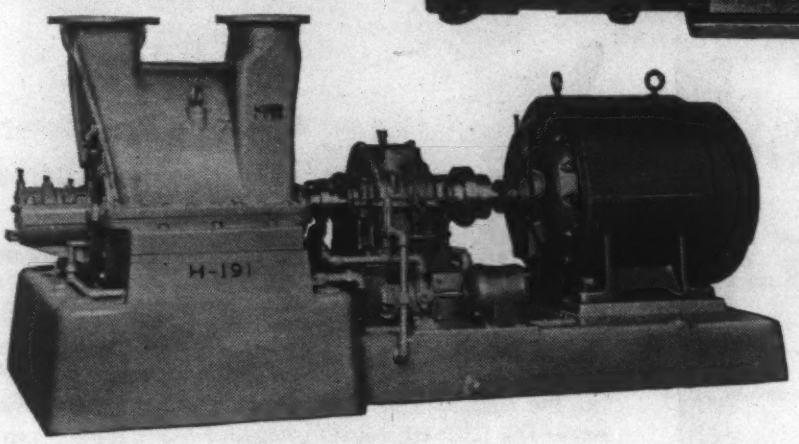
R-C *dual-ability*

PLAYS NO FAVORITES



(Right) Typical small R-C Rotary Positive Vacuum Pump, used in textile processing plant. V-belt driven from constant speed motor.

(Below) Multi-stage R-C Centrifugal unit, suitable for either vacuum or pressure service. Driven by constant speed motor through reducing gear.



Our recommendations for vacuum pumps are completely unbiased as to types. We build both Centrifugal and Rotary Positive units and will supply whichever one best suits your needs. That's R-C *dual-ability*.

During our 92 years of building equipment to handle air, gas and liquids, we've gained wide experience which can be valuable in solving your problems. Users frequently find that our *dual-ability* permits substantial cost savings, space and weight reduction, and other important advantages that provide a more profitable investment.

Our Centrifugal units are best suited for handling larger capacities at moderate vacuums, while the Rotary Positive type can provide vacuums up to 26-inch Hg. There is a wide range of standard sizes, or special units can be furnished.

ROTARY POSITIVE

Whether your needs call for Centrifugal or Rotary Positive equipment, you can be sure that Roots-Connersville will design simply, and build sturdily, to give you long, trouble-free, profitable performance.

CENTRIFUGAL

ROOTS-CONNERSVILLE BLOWER CORP.
One of the Dresser Industries
608 Superior Avenue, Connersville, Indiana

Roots CONNERSVILLE SINCE 1854

VACUUM PUMPS

ROTARY POSITIVE AND CENTRIFUGAL BLOWERS • EXHAUSTERS • BOOSTERS
LIQUID AND VACUUM PUMPS • METERS • INERT GAS GENERATORS

Ball Bushing for Linear Motion

Thomson Industries, Inc., 2905 Review Ave., Long Island City 1, N. Y., announce the standardization and production of their round shaft type ball bushing for linear motion.

In addition to the reduction of wear, friction and maintenance afforded by all types of anti-friction bearings, the ball bushings have been designed to solve two problems inherent to plain sliding linear bearings. The oil film over the exposed surface of the shaft upon which the plain bearing's operation depends deteriorates due to oxidation and becomes gummy and grit laden. Plain linear bearings require a large length to diameter ratio to prevent cocking and binding. Ball bushings reduce this dimension requirement.

Ball bushings also are said to offer the other advantages of ball bearings, such as savings from the use of smaller drive motors, gears, linkages; operating economies due to reduced load; longer life; increased reliability; less servicing; higher operating speeds; and sustained precision.

Standard ball bushing sizes vary from ¼-in. shaft size to 4 in. Sizes from ¼ in. to 1 in. vary in ⅛-in. steps; from 1 in. to 3 in. in ¼-in. steps and from 3 in. to 4 in. in ½-in. steps.

● A new holder that provides vertical adjustment for boring tools in lathes has been designed by *Bokum Tool Co.*, Detroit. The turning of a knurled screw moves the tool in a vertical parallel plane to bring it to any precision setting. The adjustment can be made quickly and conveniently, dispensing with use of shims, and can be positively locked. The knurled screw actuating the vertical adjustment has Acme thread, hardened and ground. All parts are made of alloy steel, heat treated.

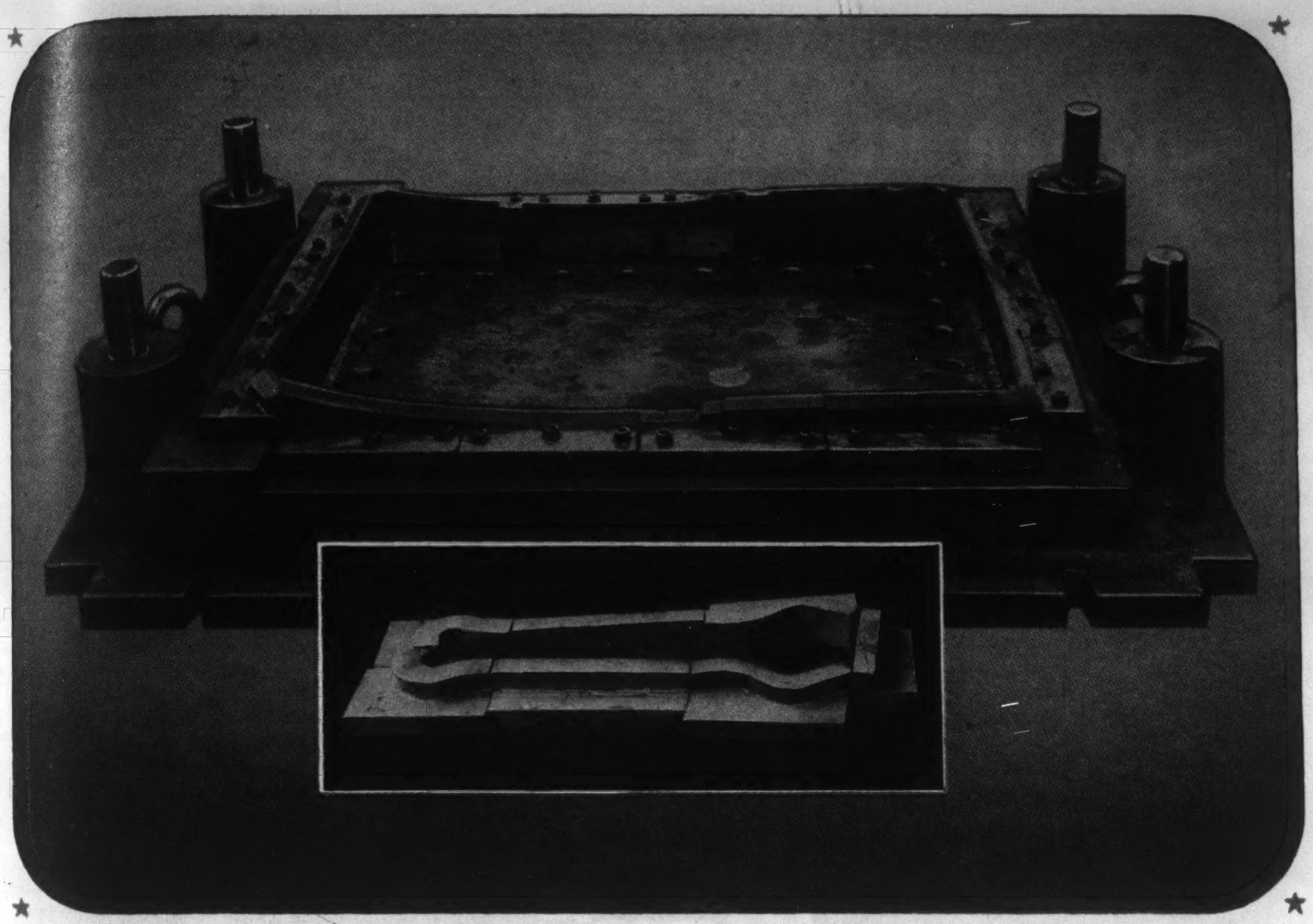
Spiral Cut Saw Blades

A principle of cutting spiral running teeth the full length of the blade body is employed by *Tyler Mfg. Co.*, 938 Pico Blvd., Santa Monica, Calif., in producing saw blades for hand coping saws or power operated jig saws.

This manufacturing method produces blades that are not limited to single cutting approach, but cut in any direction without requiring the operator to turn his saw frame or his work to change the direction of the cut. Since the blade is circular in section, its normal stock removal in one stationary stroke leaves a circle.

A cut may be made in any line or arc from this circle without blade-binding or breakage; 100% of the blade is a cutting tool. The new blade simplifies intricate work such as scroll or fret cutting.

The blades are made of oil tempered spring steel and designed to cut all woods, light metals and plastics.



When time is precious—

SPEED YOUR DIE MAKING

SAVE MONEY TOO

Write for New Booklet:

COMPOSITE DIE SECTIONS

Contains complete data on 35 Standard Die Sections, from combinations of which thousands of die shapes can be made—also full information on Special Die Sections, and how to order.

Get Your Copy—
Write for it Today.

Address Dept. MM-44

FCC Composite Die Sections are quickly available to your order. Shipment to your specifications can usually be made in five to ten days.

On large dies or small for blanking, beading or trimming, these prefabricated die parts save steel, and a vast amount of time and trouble in the die shop.

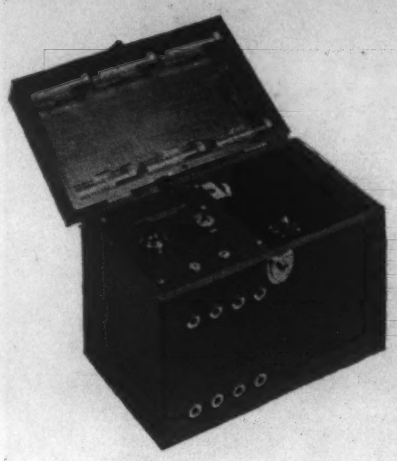
They are made of fine tool steel cutting edges in a selection of grades, electrically butt welded by a special process to non-hardenable mild steel bases. Accurate temperature control assures uniformity of behavior in heat treatment.

Further information is available from any Allegheny Ludlum field representative, or write us direct for engineering data (see details at left).

ALLEGHENY LUDLUM
STEEL CORPORATION
Forging and Casting Division
Detroit 20, Michigan

W & D-567

Micro Hardness in POWDER METALLURGY



true tests on sintered compacts

The "Micro Hardness Tester" is the device used for checking the hardness of the particles in a compact. If the hardness values of individual particles of a metallic powder, or of the compact are known, the degree of strain hardening or correctness of an annealing cycle can be ascertained.

Practical applications made on iron, tungsten carbide, steel, bronze, copper powders, etc., are shown photographically, with the results of tests, in an article by Robert Steinitz which appeared in MATERIALS & METHODS, June, 1943. This Micro Hardness Tester is the answer to many hardness-testing problems not only in powder metallurgy but also in other fields where the hardness of localized microscopic areas must be determined.*

An accurately ground diamond indenter permits measurement directly in fundamental units, easily convertible to other systems. The indenter unit, equipped with standard microscope society threads, is designed to mount on any metallurgical type microscope.

* Reprints of the above article may be obtained by writing us.

Eberbach & Son Company
LABORATORY APPARATUS & SUPPLIES
ANN ARBOR, MICH. ESTABLISHED 1843

Self-Propelled Arc Welder

The *Hobart Brothers Co.*, Troy, Ohio, announces its latest models of mobile type self-propelled arc welders. Originated to simplify welding operations in the various yards of large railway companies, this unit is also applicable for maintenance welding operations around large oil refineries, steel mills, quarries, gravel pits, and other extensive industrial plants where it is desirable to take the welding machine directly to the job.

The welding equipment consists of a 300-amp. welding generator and tank carriers for oxyacetylene welding. The door to tool chest in rear becomes a welding and work bench when opened. A Chrysler industrial 6-cylinder engine furnishes power for welding and transportation. A special cable reel has capacity for 75 ft. of both electrode and ground cable, and is optional equipment. Current supplied to the reel permits immediate welding at any desired cable length.

The unit has an automotive type transmission, three speeds forward and one reverse. It is connected directly to the welding generator. Fluid drive with rear mounted clutch permits smooth transmission of power to a transfer case which may be equipped with one-to-one, or two-to-one gear ratio, depending upon the requirements of the unit. The clutch is a dry disc type, 10 in. in dia. Brakes are four wheel hydraulic. A mechanical hand brake is on the drive shaft. All controls are automotive type, and the unit is mounted on springs and shock absorbers in front and rear.

● *Arcos Corp.*, 308 Gulf Bldg., Philadelphia 2, announces an addition to its line of electrodes for welding nickel and nickel-copper alloys. Trade-named Monend, this electrode is used in welding wrought, cast, or clad "Monel" (d.c. reverse polarity).

OUR SERVICES

Induction Hardening
Annealing
Aerocasing
Heat Treating
Bar Stock Treating and Straightening
Flame Hardening
Normalizing
Cyaniding
Nitriding
Chapmanizing
Pack or Gas Carburizing
Sand Blasting
Tensile and Bend Tests

Science and Skill DETERMINE the OUTSTANDING QUALITY of LAKESIDE'S DRAWING FURNACES

Skill backed by 33 years of experience in all phases of metal treating . . . the *latest scientific developments* in equipment, together give you the answer to all metal treating problems.

Our loading and unloading facilities are exceptional. NO waiting —NO bottleneck to hold up deliveries.

THE LAKESIDE STEEL IMPROVEMENT CO
5418 Lakeside Avenue · CLEVELAND OHIO

Solvent Degreasing Machine

The *Mabor Co.*, Clark Township, N. J., has just developed a production degreasing machine which uses a liquid jacket heating system that operates at atmospheric pressure. In this way, gentle, uniform heat is provided, thereby avoiding the danger of the solvent overheating and reducing the necessary amount of fluid in the equipment. This is accomplished because no coil or heater is located in the bottom of the tank.

Not only is there an appreciable saving in the solvent but time is saved in heating the cleaning compound. The degreaser can be heated with high pressure steam without the use of a pressure-reducing valve, or with gas or electricity without any possibility of overheating the solvent.

The degreaser is also equipped with an automatic control system that pre-heats the circulating water above the dew point. An automatic oil and grease skimming device is standard equipment and has been so engineered as to require no attention.

● For more than fifty years now, Michigan Smelting has been producing non-ferrous ingot of such high grade that it has made this company known as a thoroughly reliable and dependable source of supply. We have established a reputation for carrying out customer's specifications in every detail. Our facilities and our production techniques are equal to any demands that can be made upon us. Try us out on that next hard-to-do job!

MICHIGAN SMELTING & REFINING

Division of
BOHN ALUMINUM & BRASS CORPORATION • Detroit 26, Michigan
General Offices—Lafayette Building

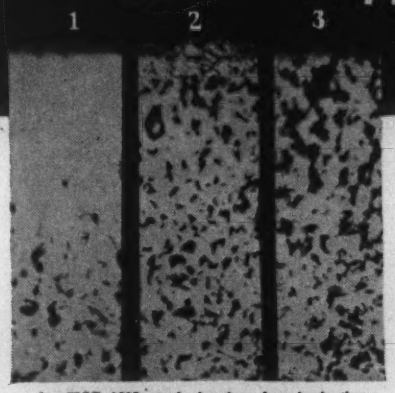
NON-FERROUS SCRAP METAL REFINERS

FOR OVER 50 YEARS

Interested in

restoring carbon

Carburizing or Preventing Decarburization?



1.—SAE 1035 steel showing decarburization before heat treatment. 2.—Same steel after short cycle heat treatment and carbon restored. 3.—After longer cycle anneal (All photomicrographs 150X).

25 Years Experience Is Available To You

With over 25 years research and practical experience in building successful equipment EF engineers are well qualified to help solve furnace problems involving carbon recovery.

Shown at left is an EF furnace similar to a continuous tube type special atmosphere furnace we developed in 1933, which restored carbon in heat treating shock absorber shafts.

An EF continuous tube type special atmosphere furnace.

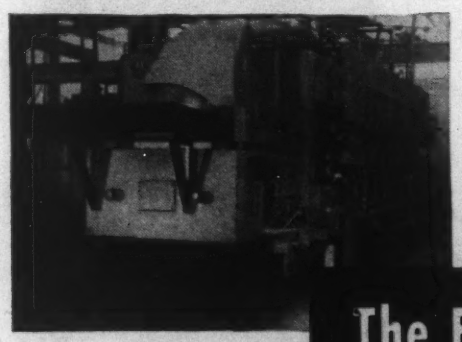
Below is a more recent installation in which carbon is restored to small products made from hot rolled rod.

Carbon restoration may be accomplished in other EF continuous and batch type furnaces equipped with our special atmosphere control.

Possibly many other furnaces now in operation could be converted for carbon restoration or the skin recovery process.

Whether you are interested in restoring carbon; carburizing; bright hardening or annealing without decarburization; or any other heating or heat treating process, EF engineers are in position to design and build equipment to do the job.

We build production furnaces for handling material in any size, shape or quantity.



An EF gas fired radiant tube furnace heat treating bolts.

We invite your inquiries

The Electric Furnace Company
SALEM, OHIO
GAS FIRED, OIL FIRED AND ELECTRIC FURNACES · FOR ANY PROCESS · PRODUCT OR PRODUCTION

Production Furnaces
For Handling Products in Any Size or Shape

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Drawing
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We Build the Furnace to Fit Your Job
THE ELECTRIC FURNACE CO.
SALEM, OHIO

For Production Furnaces, For Any Process or Production, Consult
The Electric Furnace Co., Salem, Ohio
No Job Is Too Large or Too Unusual

Preheating Oven for Plastic

The extraction of moisture from thermoplastic materials and preheating prior to feeding into the hopper of the presses, important for many jobs in injection molding departments, is of the highest importance in extrusion work. The *Despatch Oven Co.*, 619 S. E. Eighth St., Minneapolis 14, has designed an oven to remove the moisture in the material and avoid failures in extruded stock.

This preheating oven finds important applications in extrusion operations of plastics.

The oven is automatically controlled to provide balanced temperature and heat flow in all ten drawers (each 20 in. by 30 in. by 3½ in.). Forced draft horizontal air flow is provided by use of a special high velocity fan, and to assure minimum heat loss through the walls of the oven 3 in. of insulation is provided.

Capacity is provided for 100 to 700 lb. of material in an 8-hr. day.

● A new thermosetting silicone resin has been developed by *Dow Corning Corp.*, Midland, Mich., for use in formulating heat and moisture resistant paints having a hard, mar-resistant surface. This new resin, known as DC 804, is especially designed for use in formulating white finishes having properties between those of ceramic coatings and ordinary organic paints.

Forging Compound for Deep Die Forging

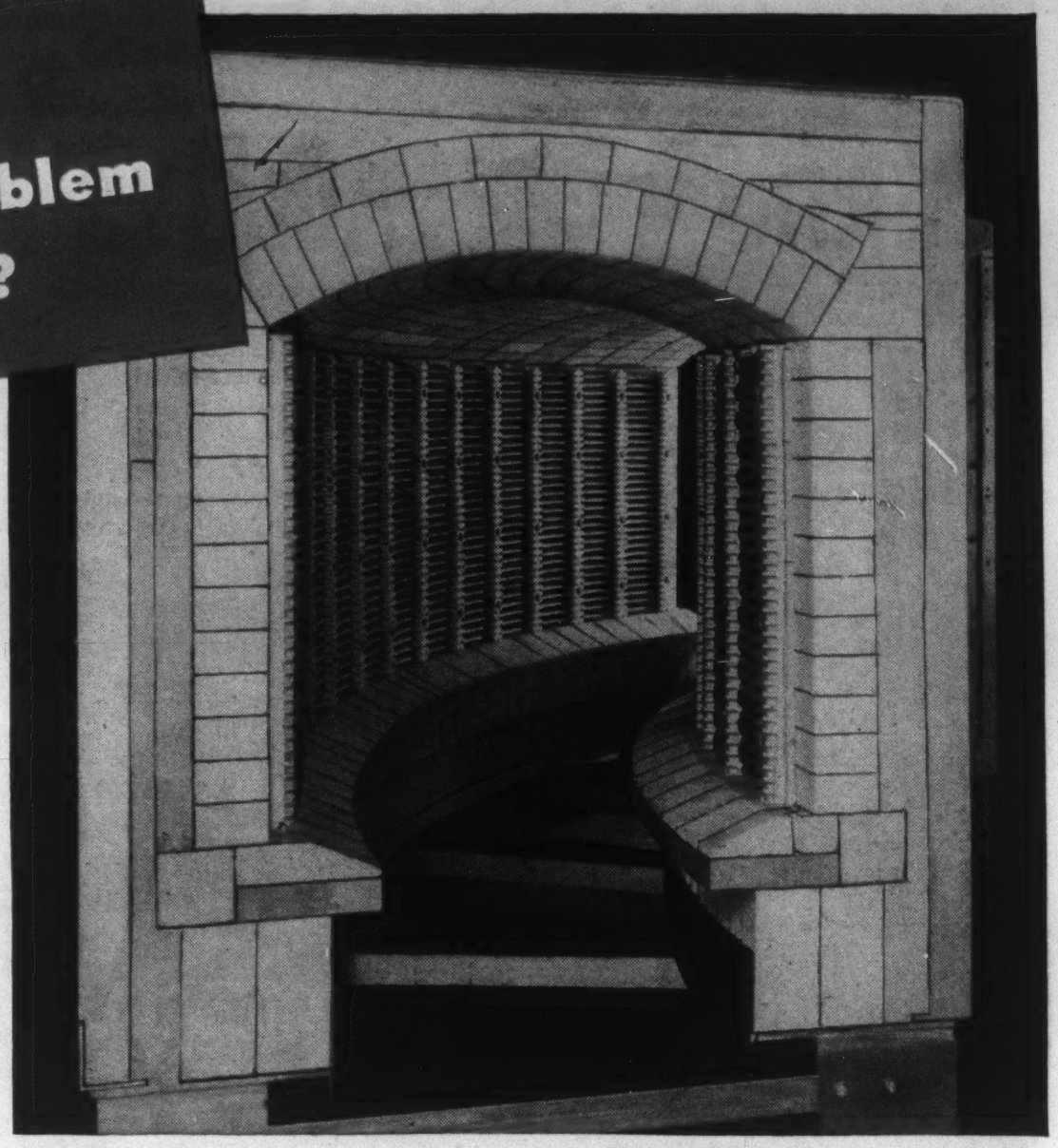
The *Brooks Oil Co.*, 315 Carson St., Pittsburgh 19, have a new forging compound for use with ferrous and nonferrous metals, to minimize stickers and eliminate build-up on dies.

This new product, known as Leadolene, deposits on the die a film of micro thickness; it is compounded without the use of graphite, and will not build up on dies. The heavy flash and dense smoke, characteristics of most forging compounds, is reduced to a minimum. It is especially adapted to deep die forging and has been successful in forging railroad car wheels.

According to the manufacturer, the compound is pharmaceutically pure.

Have you a furnace problem like this?

To find insulating fire brick that help sell a factory-built furnace unit



One of six sections of a rotary hearth furnace manufactured by the Hevi-Duty Electric Company, Milwaukee, Wis. This furnace is shipped in completely fabricated sections, which are quickly assembled on location. Note the neat appearance of the Armstrong's A-25 Insulatng Fire Brick.

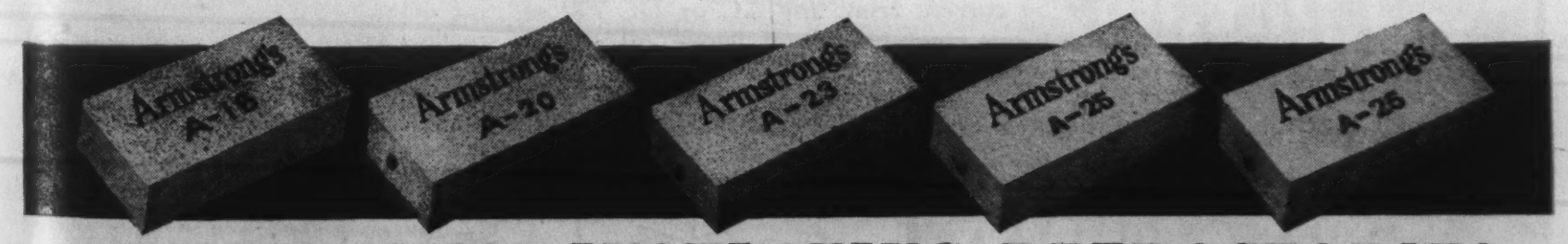
HERE'S HOW IT HAS BEEN SOLVED

TO ASSURE CUSTOMER SATISFACTION, factory-built furnaces shipped as complete units must arrive with brickwork in A-1 condition. If these furnaces are to be delivered in the same condition they left the factory, the insulating fire brick used must be strong and accurately sized and must possess a texture that provides for a tight mortar bond. And to insure continued customer satisfaction, the brick must be efficient to provide operating economy.

Armstrong's Insulating Fire Brick serve well in applications of this type. Their extremely accurate sizing, to tolerances of $\frac{1}{32}''$, and their uniform, fine-grained composition permit thin, heat-tight joints and an exceptionally strong mortar bond. These brick are light in weight and efficient, too, and they possess the strength necessary to give long service without excessive maintenance.

All five types of Armstrong's Insulating Fire Brick, for temperatures from 1600° to 2600° F., have high insulating efficiency, great strength, high resistance to spalling, light weight, low heat storage, uniform size and uniform texture.

To help you solve your special problems, the "know-how" of Armstrong's engineers is at your service without obligation. For full information, write today to Armstrong Cork Company, Insulating Refractories Department, 5508 Mulberry Street, Lancaster, Pennsylvania.



ARMSTRONG'S INSULATING REFRACTORIES

MANY USES — BIG SAVINGS WITH CERRO LOW TEMPERATURE MELTING ALLOYS

CERROMATRIX—250° F. For securing punch and die parts; anchoring machine parts; short run forming dies, etc.

CERROBEND—158° F. As a filler for bending thin-walled tubing—melts out in boiling water. Also used for automotive and aircraft assembly jigs, forming dies, etc.

CERROSAFE—165° F.-190° F. Used for proof-casting cavities in molds, forging dies, duplicate patterns, etc.

CERROBASE—255° F. Used in electroforming dies, molds, etc.

CERROTRU—281° F. Metal molds for wax patterns used to make precision castings.

CERROLOW—117° F.—CERROLOW—136° F. and CERROLOW—174° F.

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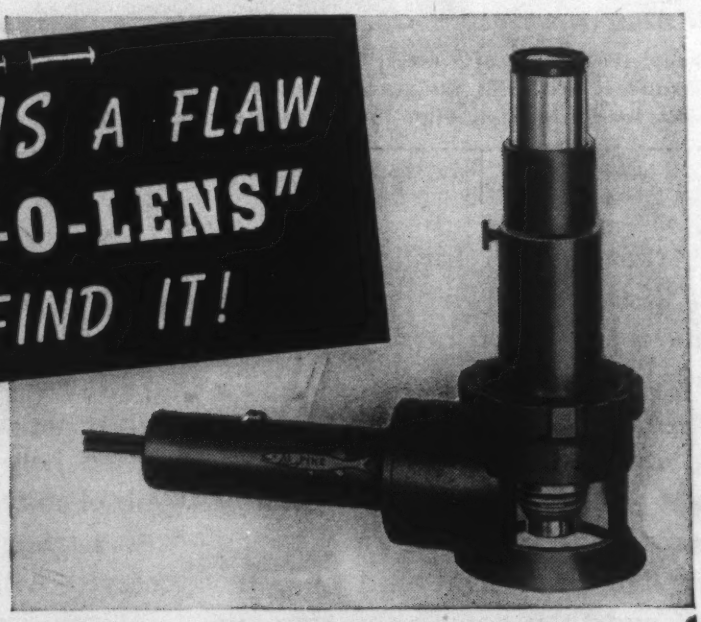
CERRO DE PASCO COPPER CORPORATION
40 WALL STREET **NEW YORK 5, N. Y.**

IF THERE IS A FLAW "FLASH-O-LENS" WILL FIND IT!



The new FLASH-O-LENS offers foundry-men, machinists, and many others engaged in producing metal parts an efficient, economical means of examining the most minute defects during routine inspections.

FLASH-O-LENS consists of a portable 40x microscope combined with a perfect source of illumination in one convenient, compact unit . . . They are available in several models—powered by either standard flash light dry cells or by current from any AC or DC outlet—and with a selection of various combinations of lenses, all interchangeable in the one lens housing.

Send today for illustrated Catalog O describing the new FLASH-O-LENS

E. W. PIKE & COMPANY
Manufacturers of Illuminated Magnifiers
PIKE REG U.S. PAT. OFF
ELIZABETH 3, N. J.

Thermal Protector

Manning, Maxwell & Moore, Inc., of Bridgeport, Conn., announce a new thermocouple actuated limit switch. The manufacturer states that its uses include providing protection in air ducts on industrial ovens, dryers, bearings of large motors, blower wheels, flue gas stacks of boilers, plastic injection presses, reheaters, etc.

The temperature chosen as the high limit is set by an operating knob located inside the case where it will not be tampered with. If this temperature is reached, the device will stop the apparatus before excessive damage is done, or it can be arranged to sound an alarm or light a light. If desired, either or all of these functions can be performed at the same time.

In addition to protection from excessive temperature, the device will "fail safe" in case of burning off or breaking of thermocouple, failure of power supply, tube or mercury switch. A still further protection is provided by a manual reset. This makes certain that something is done to correct the cause before the equipment is damaged or production is seriously interrupted.

The thermal protector is designed with two ranges, 100 to 1000 F using an IC couple, and 800 to 2000 F using an AC couple with an accuracy of 2% of the range at a set point. Two or more couples may be connected in series if compensated to ambient temperatures of 50 to 135 F and a relative humidity up to 100%.

The current characteristics are 115 to 230 volts, 60 cycle, AC 15-20 watts. There are no open contacts in the device, and the circuit for the signal and power input to the apparatus is a standard 4-amp., 250-volt mercury switch. The case for this device is designed for universal mounting either flush or wall.

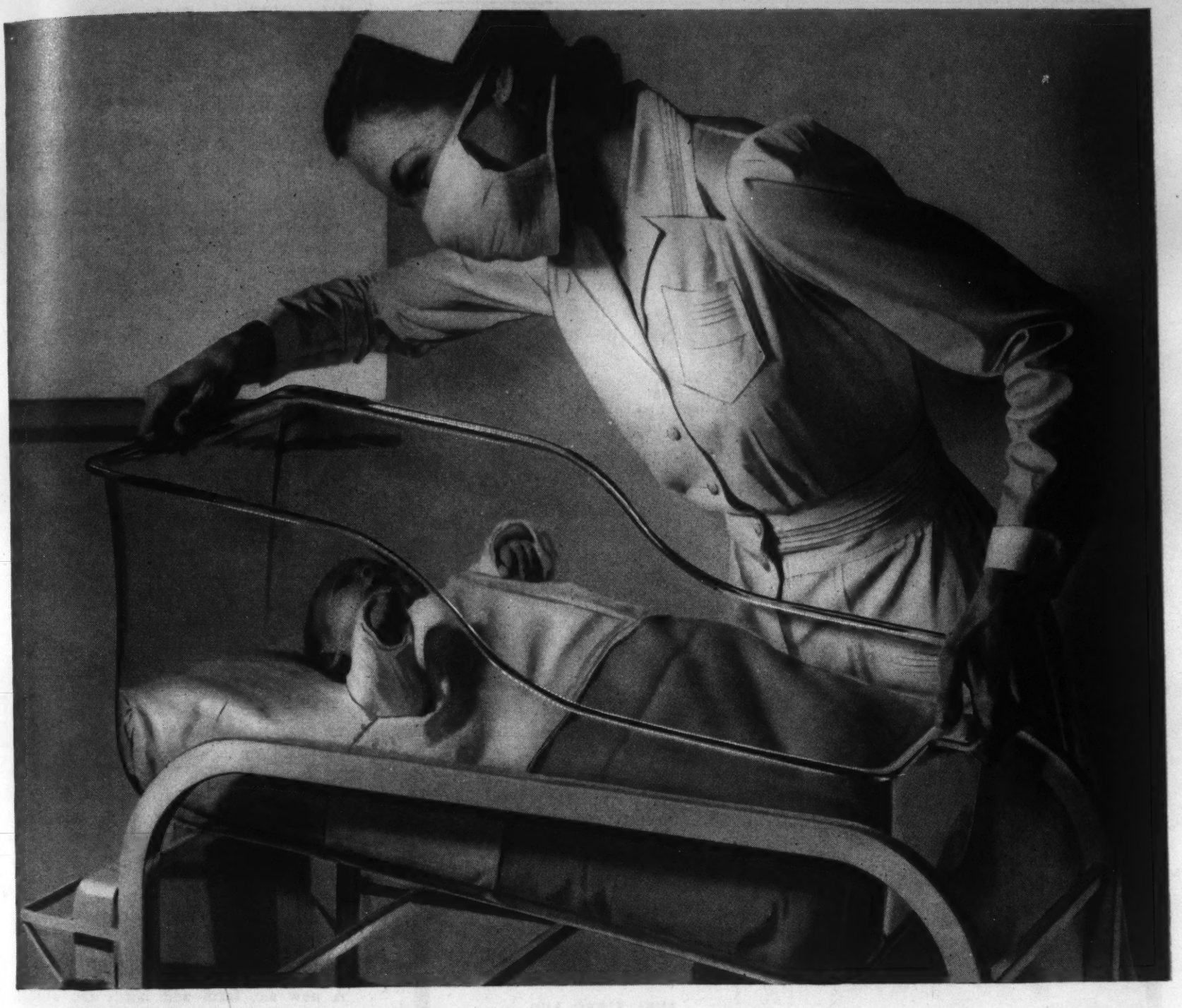
● A unique seal for rotating shafts has just been announced by *Sealol Corp.*, 45 Willard Ave., Providence 5, R. I. This new "Sealol CB" seal is designed for original equipment or replacement, and is said to make stuffing boxes obsolete. It is designed to seal leaking shafts simply, permanently and economically, and to exclude all foreign material.

Welding Cable Splicers

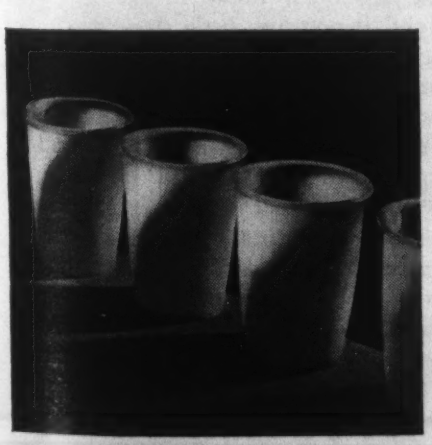
A new line of welding cable splicers has been announced by the *Tweco Products Co.*, Wichita 1, Kan. The new product is a companion to the detachable connectors already offered by the company.

The cable splicers provide a quick repair of broken cables or salvaging short lengths. A simple clamp cable connection on each end of the splicer, with provision to solder between the cable ends, assures an efficient connection. A fibre sleeve covers this permanent cable splicer.

The splicers are made in three sizes to cover the full range of welding cables. Size "S" for small No. 4, 2, or 1 cables; Size "M" for medium No. 1/0 or 2/0 cables; Size "L" for large 3/0 and 4/0 cables.



HE'S SAFE . . . HE'S IN SIGHT . . . HE'S IN "LUCITE"



WHAT'S NEW

Tumblers of molded nylon are translucent, light-weight, attractive, and pleasant to the touch, yet they stand hard knocks, hot drinks—and steam-sterilizing. Dropped on concrete terrace or tiled bathroom floor . . . they do not break. Manufactured by DuBois Plastics, Buffalo, N. Y.

No drafts reach *this* baby! Yet his nurse can always see him. He's safer, that's sure, than the infant surrounded by blankets in the old-style bassinet.

For filling this long-standing hospital need, credit the man who discovered that this transparent, sanitary "baby-basket" *could be formed from a single sheet of Du Pont "Lucite."* The light weight of "Lucite" acrylic resin makes the product easy to handle . . . its strength helps make it last for years.

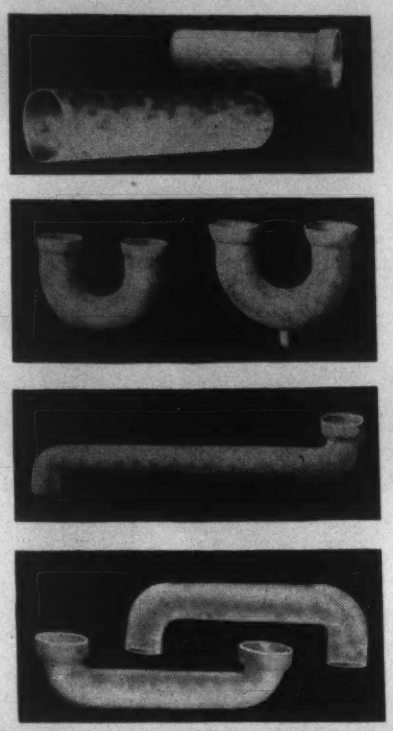
Thus another new and better product steps into a market ready and waiting . . . because of a man-with-an-idea who knew his Du Pont plastics.

Just so, in *many* fields new products are made more beautiful, more serviceable, more salable by one or more of the Du Pont plastics. These all help to show that the manufacturer who knows these plastics well has a big head start over the man who doesn't. Write for literature on these plastics today. E. I. du Pont de Nemours & Co. (Inc.), Plastics Dept., Room 418, Arlington, N. J.

The "Infanette" is made by W. P. Campbell Mfg. Co., Los Angeles, Cal., for American Hospital Supply Corp., Chicago, Ill.

DU PONT
REG. U. S. PAT. OFF.
Plastics
BETTER THINGS FOR BETTER LIVING
. . . THROUGH CHEMISTRY

NOW A MUCH NEEDED ENGINEERING SERVICE



Heretofore the design and selection of silica ware units, for processes involving extreme temperatures and highly corrosive conditions, has been on the basis of fitting various pieces of equipment together.

Amersil now offers an engineering service which includes development, research, design, controlled manufacture of major silica ware units, selection and purchase of auxiliaries, all under one contract one responsibility.

Because of this integrated design and manufacturing service, Amersil is able to guarantee performance.

AMERSIL COMPANY Inc.

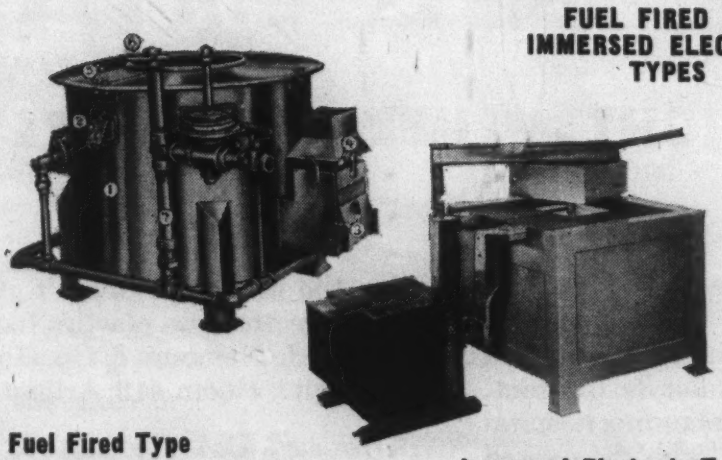
ENGELHARD

CHESTNUT AVENUE HILLSIDE 5, N. J.

IMPROVED

SALT BATH FURNACES

FUEL FIRED AND IMMERSED ELECTRODE TYPES



Fuel Fired Type

Over 20 standard sizes or built to meet your needs. Note convenient lighting and observation port. Accessible clean-out. Ventilated stack connection . . . keeps useful heat inside furnace. Single valve operation.

Immersed Electrode Type

27 standard sizes. Temp. range from 4000°-2400°. With or without conveyors for continuous Salt Bath Heat Treatment and Quench.

Write wire or phone—there is a Dempsey representative near you

FURNACES: Oil-Gas-Electric-"TAILORED" by DEMPSEY Meet every Heat Treating Need

DEMPSEY FURNACE

DEMPSEY INDUSTRIAL FURNACE CORP.

Hole and Washer Cutter for Heavy Duty

A new heavy duty hole and washer cutter for production work, which cuts round holes or washers from steel plate, or any other material up to ½-in. thickness, is the product of *Wyzenbeck & Staff, Inc.*, 838 W. Hubbard St., Chicago 22.

The tool cuts as accurately to size as a boring tool. It fits 1-in. drill chuck, or can be supplied with Morse taper shank. Tool holders and body are of heavy steel.

Balanced cut is insured by two standard high-speed cutting off blades. Shanks are interchangeable and the tool is furnished complete, with ⅛-in. hexagon shank to fit any 1-in. drill chuck, or with No. 3 or No. 4 Morse taper shanks. Although the hole cutters are furnished with hardened pilot pin, they can be used with a pilot drill, if desired.

● The *Asco Corp.*, 874 E. 140th St., Cleveland, announces a new tool for speeding certain machining processes. This tool, called Auto-Arb, is an expanding arbor for use on secondary operations where work-piece is held by the inside diameter. Its design permits chucking and unchucking work-piece without stopping the spindle when used on a screw machine or lathe with standard collet. It can also be used to good advantage on drill presses or milling machines with collet devices.

New A.C. Arc Welder

A new a.c. farm and home arc welder especially designed for operation on single-phase lines of limited capacity supplying rural areas and small communities has been announced by the *General Electric Co.*, Schenectady, N. Y.

The new welder is furnished in two ratings, 130 and 180 amperes, either with or without capacitors. Small in size and light in weight, it occupies little floor space and can be easily moved about. It has two plug-in connections for the electrode cable, one for use with 1/16-in. or 5/64-in. electrodes and one for 3/32-in., 1/8-in., and, in the larger rating, 5/32-in. electrodes.

A welding current scale located on the front of the welder is calibrated in electrode sizes rather than in amperes. Current adjustments are made by means of a hand crank which provides an infinite number of settings to accommodate the size electrode being used. An electrode gage consisting of a series of calibrated notches on the bottom edge of the front panel makes possible quick identification of electrode size.

Designed into the new welder are several safety features which protect both the operator and equipment. The welder is constructed to use the lowest possible welding voltage consistent with good welding practice, and is enclosed in an electrically grounded metal case. In addition, it is protected against overload by a built-in circuit breaker.

"ETHYL" CHANGES A TIRE FOR THE BETTER...

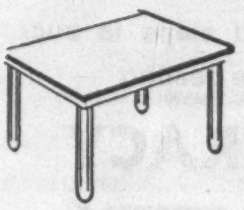
adds distinction and durability to many products

Made by Lyon, Inc., from Celanese "Celcon"

The new plastic "Whitewalls", made by Lyon, Inc., Detroit, show how easily and economically ethyl cellulose trim can keep non-plastic products *in trim* even in rigorous outdoor service.

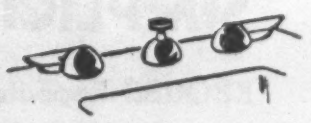
Unique in its combination of impact strength, dimensional and temperature stability, moisture and chemical resistance, color permanence, and fabricating economy, ethyl cellulose was the logical material for the job.

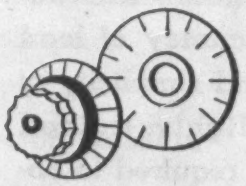
Ethyl cellulose is available in easily-formed sheets, such as used for these "Whitewalls", or it may be fabricated into finished products by high-speed injection molding or screw extrusion. Investigate its possibilities for improving *your* product's salability today.



Wear-resistant, washable trim for tables, sinks

Colorful fixtures for bathrooms





Dimensionally stable dials and trim for radios

HERCULES

CELLULOSE ACETATE
CELLULOSE NITRATE
ETHYL CELLULOSE

For general-purpose production plastics

Hercules does not make plastics or molding powder, but supplies the high-quality cellulose derivatives from which they are made. For data, please write to

HERCULES POWDER COMPANY INCORPORATED 907 Market Street, Wilmington 99, Delaware

CP-69

Master Hands on Intricate Jobs use

SHAWINIGAN CARBIDE

SHAWINIGAN

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EMPIRE STATE BUILDING,
NEW YORK 1, N.Y.

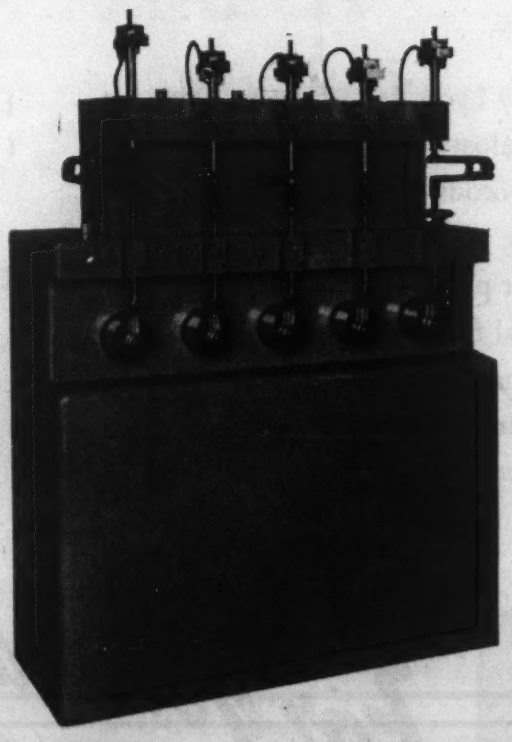
"TESTING" SUCCESS

Two important steps to success in fatigue testing —

ACCURACY
SIMPLICITY

KROUSE Repeated Stress Testing Machines are designed for accuracy of load application and simplicity of operation. Highly trained personnel not required to obtain accurate results.

To-day most service failures occur under REPEATED STRESS. For best "in service" testing use KROUSE Repeated Stress Testing Machines.



KROUSE 5 Unit Spring Machine 1 in. stroke, 250 lb. load, cut-off for each unit. Adapted for many types of specimens, such as sylphon bellows, vibration insulators and diaphragms.

KROUSE TESTING MACHINE COMPANY

573 E. Eleventh Ave. Columbus 3, Ohio

Attachment for Surface Grinders

A new high-speed surface grinder attachment, known as the Stafford Blitzrev, is being manufactured by the *D. & S. Model Co.*, 3114-34 E. 3rd St., Dayton 3, Ohio. The attachment can be installed on most standard makes of surface grinders and

Speeds of 10,000 and 15,000 r.p.m. are attainable with this surface grinder attachment.

permits the operator to use small grinding wheels from ⅛-in. mounted quills to 3-in. dia. wheels.

Speeds of 10,000 and 15,000 r.p.m. are attainable with the standard 2-step pulley. A special pulley is obtainable if higher speeds are required. An air flushing principle is used whereby a fan mounted on the revolving shaft inside the housing sets up an airflow outward, preventing entrance of dirt and dust.

A drive pulley is mounted on the surface grinder spindle, replacing the standard 7-in. wheel. This pulley, by means of a belt, drives the high speed spindle of the attachment. A dovetailed arrangement allows a forward and backward movement of the attachment, permitting grinding over the full surface of the magnetic chuck with a 2-in. dia. wheel. Attachment may also be swung through 360 deg., allowing grinding farther to left or right, increasing the capacity.

Spray-Coat for Metals and Plastics

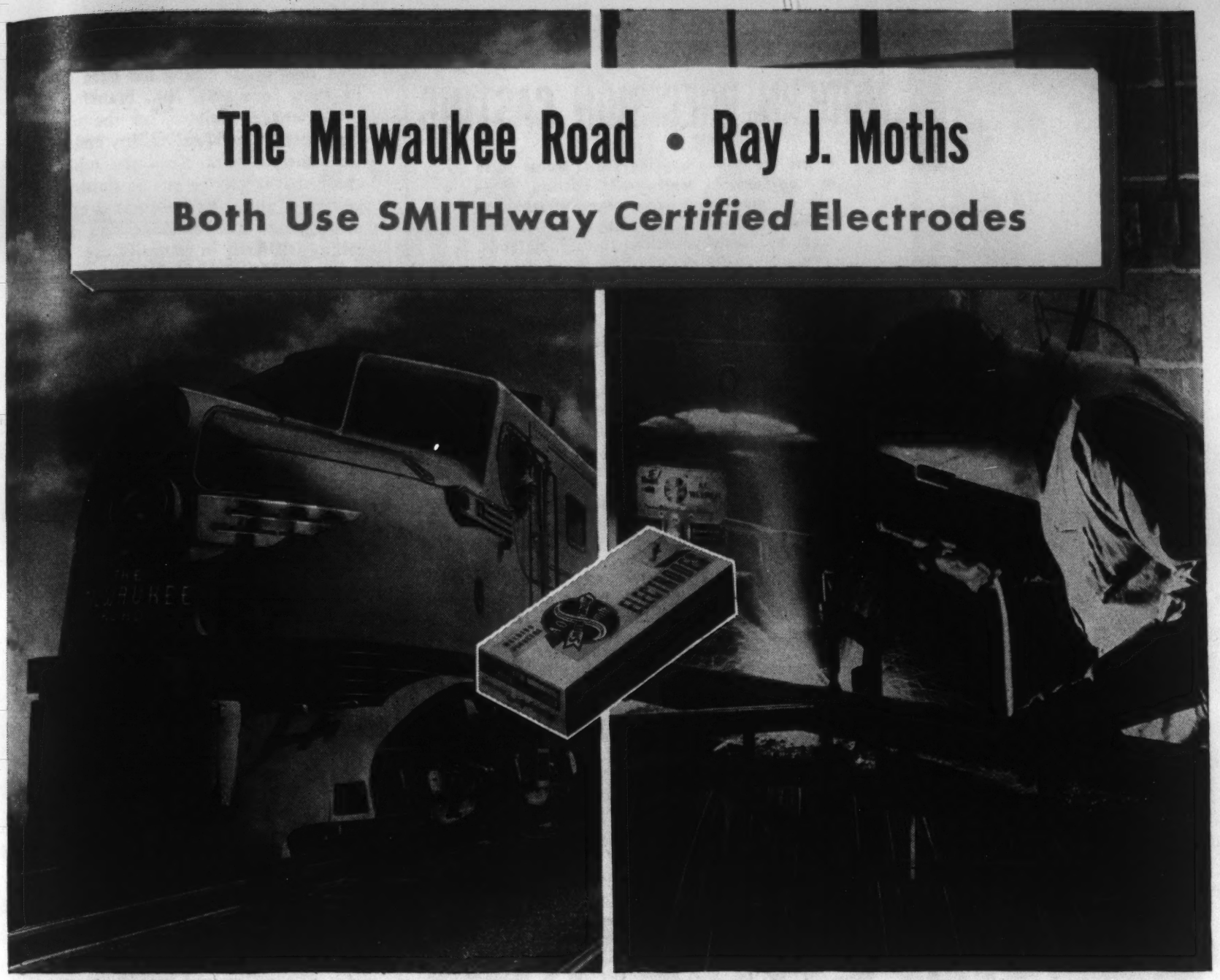
A new coating that produces a lustrous hammered effect in a single spray-coat application is announced by *Maas & Waldstein Co.*, 438 Riverside Ave., Newark 4, N. J. The new product, named Motletone, is available as an air-dry or baking finish.

It may be used on metal equipment, such as automobile heaters, air conditioning units and metal furniture. It may also be used on molded plastic products and on wood, when a metal-like hammered finish is desired.

According to the manufacturer, the new coating tends to hide weld dimples, scratches and other small defects, and is especially recommended where low cost finishing is required.

The Milwaukee Road • Ray J. Moths

Both Use SMITHway *Certified* Electrodes



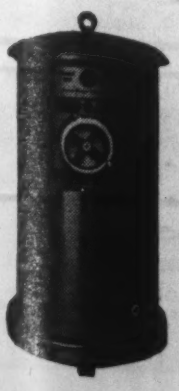
Courtesy The Milwaukee Road

The Milwaukee Road, one of America's great transcontinental railways, is famous for its fleet of streamlined Hiawathas, one of which is shown above. In the building of its own rolling stock, and in maintenance, The Chicago, Milwaukee, St. Paul, & Pacific Railroad Co. knows that the proof of SMITHway Certified Electrodes is in production—*and in service.*

Ray J. Moths Co., Inc., Milwaukee, specialized manufacturers of concrete-form construction equipment, know the value of A. O. Smith welding research, too. For light work, no less than for "big stuff," SMITHway Electrodes take the risks out of welding—make welding the modern production tool for *all* kinds of jobs, in *all* kinds of plants and shops.

SMITHway Welding Electrodes — Made *by* Welders...*for* Welders

Through Leading Distributors Everywhere

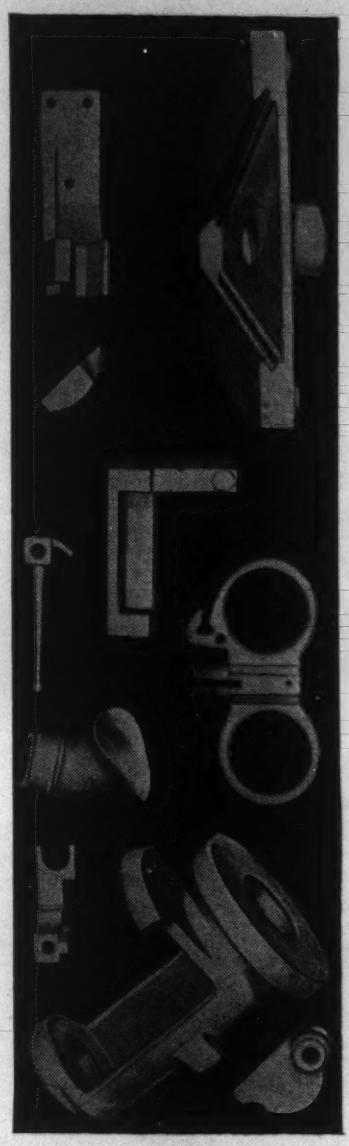


SMITHway A. C. WELDERS

Six models, including three new models of 150-, 200-, and 250-ampere capacity. Heavy-duty models of 300-, 400-, and 500-ampere capacity. Write for specifications and prices.

A. O. SMITH Corporation

NEW YORK 17 • PHILADELPHIA 5 • PITTSBURGH 19 • CLEVELAND 4 • ATLANTA 3
CHICAGO 4 • TULSA 3 • MIDLAND 5 • DALLAS 1 • HOUSTON 2 • NEW ORLEANS 18
SEATTLE 1 • SAN FRANCISCO 4 • LOS ANGELES 14
INTERNATIONAL DIVISION: MILWAUKEE 1



An OPEN LETTER on

MODERN PRECISION CASTING

If you are now producing small metal parts by conventional methods of casting, forging or machining, you may be able to realize substantial savings in production costs by using precision casting methods.

Developed to meet wartime production demands, this new process may be applicable to your products particularly if machining costs are high or runs are short with high costs.

Precision casting is being used today to produce a wide range of parts in ferrous and nonferrous metals including high temperature alloys and varying in size from a fraction of an ounce to several pounds.

Compared to other industrial equipment, the cost of a complete precision casting plant remains surprisingly low.

As a dealer in precision casting equipment and supplies we offer detailed information to set up and operate a precision casting plant for your production.

Descriptive circulars of equipment and price lists of *supplies* furnished on request.

ALEXANDER SAUNDERS & CO.

Successor to J. Goebel & Co.—Est. 1865

Precision Casting Equipment and Supplies

95 BEDFORD ST. NEW YORK CITY 14

JOHNSON XLO *Music Wire*

Special Alloy Finish

Ideal for products coming in contact with hands—no tarnish—no oxidization —superior to tin. This new Johnson smooth satin alloy finish reduces tool wear — solders easily — will withstand temperatures up to 700° Fahrenheit. Valuable qualities that Johnson research and modern production have created for post-war manufacturing.

JOHNSON STEEL & WIRE CO., INC.

WORCESTER 1, MASSACHUSETTS.

NEW YORK AKRON DETROIT CHICAGO LOS ANGELES TORONTO

Spiral Tubing

A new spiral tubing has been developed by *Pratt Industries, Inc.*, Frankfort, N. Y.

Advantages claimed for the tubing are light weight, extreme rigidity and low cost. On concrete form work the tubing is so cheap that it may be left on finished pillars, piers and posts. Its lightness is emphasized in irrigation and drainage uses where the tubing is already in extensive use. One man can carry 60 ft. of the tubing in 20-ft. lengths, and can lay several thousand ft. a day.

The tubing is spirally formed from metal strip (steel or nonferrous) with edges joined in a continuous four-ply lock-seam. Tests show that seams hold at a pull of 2135 lb. The spiral "backbone" gives the tubing its rigidity, demonstrated in tests when a 2-ft. section of tubing, stood on end, supported over a ton without measurable distortion. Wall thickness of the tubing thus tested was 0.030 in.

Other uses for this spiral tubing are in air-conditioning ducts, blowers for ensilage cutters, pulverized-coal circulating lines, stacks, stack-liners and flues, and backing for rubber-lined pipe.

Pneumatic Horizontal Grinders

The *Master Pneumatic Tool Co., Inc.*, Orwell, Ohio, has recently put on the market a new line of power horizontal grinders.

A few of the features of horizontal grinders reported by the manufacturer are: (1) Industrial hard chromium used on main wearing parts; (2) lighter weight because of magnesium housings which are light and rigid; (3) maintained speeds—correct load and free speeds are controlled by quick acting, push valve governor, regardless of fluctuating air pressure, and will not "run away" with use; (4) sure grip handles—wheel end and throttle handles are of new design to give a better grip.

The horizontal grinders are useful in the metalworking trades, and in all metal finishing plants.

Measuring Molten Metal Temperatures

A new portable thermocouple for measuring molten aluminum temperatures and regarded as suitable for measuring lead, babbit, zinc, type metal and similar low melting metal temperatures has been developed and will be introduced soon by the *Brown Instrument Co.*, Philadelphia.

Metal temperatures can be measured below the surface of the bath in a matter of seconds, while the readings are unaffected by couple wire conditions; parasitic current generation is wholly absent at the hot junction.

In operation, the couple is immersed several inches below the surface of the bath and held there until a steady reading is obtained on the measuring instrument, usually 10 to 12 sec. The couple is then withdrawn, adhering metal being removed by shaking the handle.

SURFACE COMBUSTION CORPORATION

Since 1921

Surface Combustion Corporation manufacturers of heating and heat treating furnaces, both of the direct fired type and of the controlled atmosphere type, have used Spencer Turbo Compressors since 1921. In addition to manufacturing special furnaces, Surface Combustion makes a complete line of Gas burning equipment as well as Standard furnaces for every heating and heat treating operation.

Spencer Turbos have been the first choice of a majority of the furnace and oven manufacturers for a quarter of a century. Here are some of the reasons why:

1. Constant pressures maintained regardless of load.
2. Simple—sturdy construction. Operates with low maintenance for a life time.
3. Wide clearances. Only two bearings to lubricate.
4. Unusually quiet. Practically no vibration.
5. Standard designs meet all requirements — single and multi-stage—35 to 20,000 cu. ft. ⅓ to 200 Hp.; 8 oz. to 5 lbs.

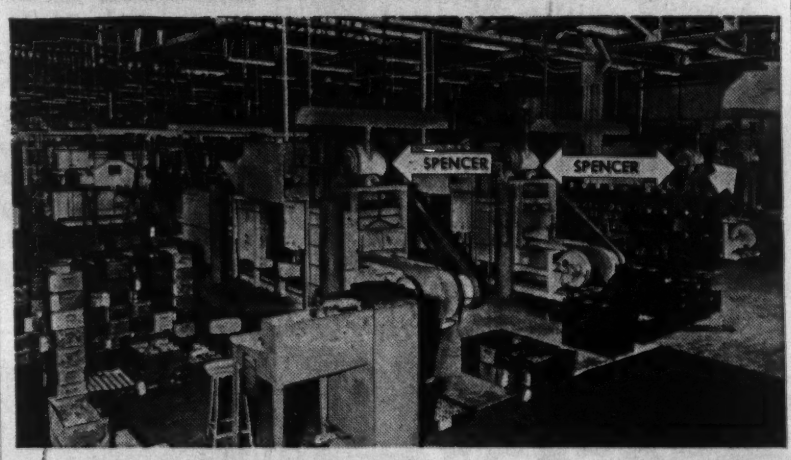
Spencer Turbos are described in the following bulletins. Why not bring your files up-to-date—now?

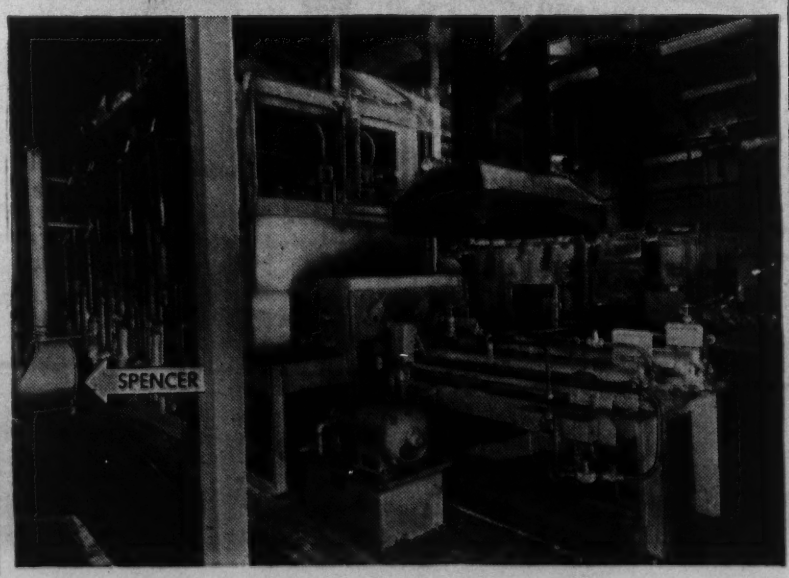
Technical Bulletin	No. 126	Four Bearing	No. 110
Data Book	No. 107	Blast Gates	No. 122
Gas Boosters	No. 109	Foundries	No. 112

THE SPENCER TURBINE CO. • HARTFORD 6, CONN.

280-D

SPENCER HARTFORD TURBO-COMPRESSORS





PRECIOUS METALS
for Industry

APW

PLATINUM

Sheet, Wire, Tubing, Gauze and Fine Foils.
Laboratory Wares of all descriptions; Stills, Retorts, Electrodes, and Special Process Equipment to order.
Catalysts of the Platinum Metals; Oxides, Sponge, Black and Chlorides. Platinum and Palladium on Carriers.
Palladium, Iridium, Osmium, Rhodium and Ruthenium.

GOLD

Sheet, Foil and Ribbon, pure and in alloy. Seamless Tubing. Laboratory Apparatus and Process Equipment. Karat Golds. Fine Gold Anodes.

SILVER

Fine, Sterling and Coin. Sheet, Wire, Circles and Foil. Fine Silver Anodes. Rolled, Cast or in Shot Forms. Silver Brazing Alloys and Fluxes for every industrial requirement.

Send for our new Folder M-20

THE AMERICAN PLATINUM WORKS
231 N. J. R. R. AVE., NEWARK 5, N. J.
PRECIOUS METALS SINCE 1875

New Dial Indicators

Three new "A" size dial indicators have been put on the market by *Federal Products Corp.,* Providence, R. I. The overall bezel diameter of these new models is only 1¼ in. These new indicators are used where the design of a dial indicator gage may be such that there is not space enough for a large indicator, or where the gage is portable, and weight is a factor.

A new movement is built in these indicators which results in low friction, full-jeweled action. These new indicators are said to be sensitive and accurate, and have good repetitive accuracy.

They are regularly furnished with the American Gage Design Committee (A.G.D.) bracket back, or with post or flat type; special backs are also available. The indicator dials can be rotated to set the zero.

Low Temperature Silver Brazing Alloys

With the price of silver increased approximately 20 cents per troy oz., the two new silver brazing alloys featuring lower silver content just announced by *Handy & Harman,* New York, should be of interest to everybody working in metals. The new alloys are called Easy-Flo 45 and Easy-Flo 35.

As its name implies, Easy-Flo 45 is a 45% silver alloy. In addition, it contains copper, zinc and cadmium. One of its features is a low melting range—1120 to 1145 F. The joints produced between ferrous, nonferrous and dissimilar metals are strong, ductile, leak-tight.

It offers the advantages of alloys with a higher silver content but, due to less silver in its composition, provides an economy to help offset the increase in the price of silver. It offers an opportunity for manufacturers to economically produce joints between ferrous or nonferrous metals which are high in strength and ductility, and is appropriate to use in places where a higher working temperature is not objectionable.

New Three-Angle Turret Diamond Holder

The *Diamond Tool Co.,* 938 E. 41 St., Chicago 15, offers a new automatic, self-centering, turret diamond holder which, when used either in the adapter of a center grinder or in conjunction with a magnetic block on a surface grinder, enables the grinder operator to use the diamond at three different degree angles: 30, 20, 10.

The mechanical action of this turret holder automatically centers the diamond point in each of the three varied angles directly at the point of grind on the grinding wheel.

This accessory is said to double the life of the diamonds, lessen the consumption of wheels, improve the accuracy of the grind, and avoid destruction of diamonds by wheels becoming "out of round" due to dull diamonds with the consequent beating of the diamond by the "out of round" wheel.

OXYGEN FREE HIGH CONDUCTIVITY COPPER

OFHC
REG. U.S. PAT. OFF.

- Hitherto the distribution of O.F.H.C. Copper has been restricted to certain special end uses such as electronics.
- O.F.H.C. Copper and a few special dilute alloys thereof are now available for most uses.

THE AMERICAN METAL COMPANY, LTD.
61 Broadway, New York, N. Y.

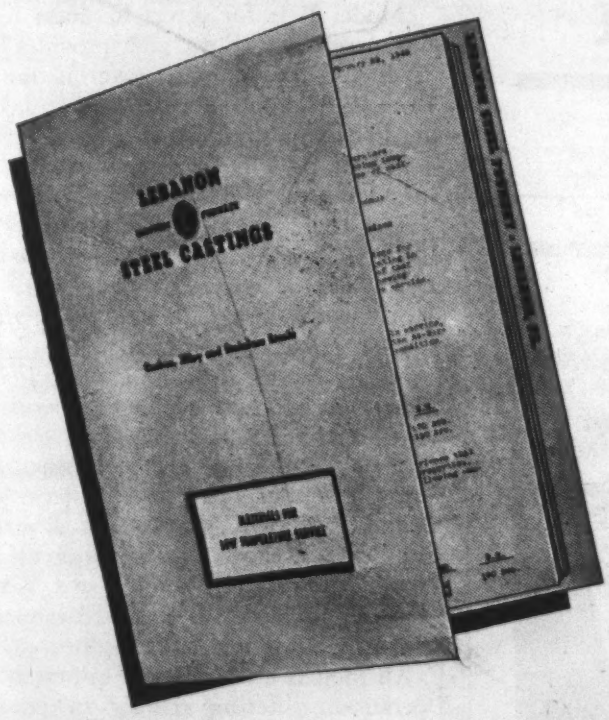
THE TEMPERATURE RANGE:

32°F to -300°F and below

THE RECOMMENDED ALLOYS:

Ⓛ 19... Ⓛ 22... Ⓛ 205

Send for Complete Low Temperature File!



Gives Chemical Analyses . . . Physical Characteristics . . . Impact Values

The folder illustrated was designed to be slipped in your file "as is." It comes to you as a complete, permanent, easy-to-find, easy-to-use data file on Lebanon Circle L 19 . . . L 22 and L 205. All data has been exhaustively tested. Information includes chemical analyses of both ferritic and austenitic type materials, physical characteristics, Keyhole and "V" Notch Charpy impact properties at various temperatures. Write today for your free copy.

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More than 340 Cleaning Compounds are now made under the PERMAG trade name to meet the growing demands of industry.

● *Detrex Corp.*, Detroit 3, Mich., announces a new product, Triad PR, a protective coating for spray booth side walls. The compound, applied to the side walls of either wet or dry spray booths with brush or spray gun, provides a light-reflective finish that withstands mild abrasion. This white surface improves visibility in the booth and can be flushed off with water or steam carrying all surface deposits with it.

Hardness Gages

Announcement of two new hardness gages, Model B and Model B-75, for determining variations in hardness of aluminum and its alloys, copper, brass and other nonferrous metals, has been made by *R. A. Webster*, 422 Twentieth St., Santa Monica, Calif.

These gages are designed to identify heat-treated materials from those which have not undergone heat treatment, to recognize parts made from an improper or substandard alloy, to differentiate between soft and work-hardened materials, to test for proper response to heat treatment and to segregate material in stock. Both are small, portable and easily operated merely by compressing the handles, which actuates the penetrator.

Model B is for direct hardness readings on aluminum alloys and provides a dial reading from 1 to 20, covering the range from soft aluminum to heat-treated and aged strong aluminum alloy.

Model B-75 is for direct hardness readings on brass and other nonferrous metals within the range of soft brass to full hard brass. It is similar in all respects to Model B except for shape of penetrator, which provides a somewhat greater sensitivity and shorter range of hardness.

While Model A is used where it is necessary only to know whether the work being tested is harder or softer than some definite standard—and it is not important to know how much harder or softer—Models B and B-75 will give an actual hardness number and show by a reading the hardness of the material being tested. Readings obtained on Models B and B-75 can be compared to other standard hardness scales.

All models are similar in appearance and operation, differing mainly in penetrator design, type of reading and range of hardness each tester will accommodate. Each model is equipped with a cylindrical anvil, enabling the testing of sheet, strip, tube or extrusions.

Actual pressure of the penetrator is applied by a spring load and is independent of pressure applied to gage handles; thus, consistent, accurate readings are assured even by inexperienced operators.

Hardness tests can be performed upon stock of any shape due to the anvil design. Capacity includes all thicknesses up to and including ¼ in.

● *National Research Corp.*, Boston 15, Mass., is now preparing limited quantities of gas free metals for experimental work. Metals and alloys that lend themselves to vacuum melting can be furnished in ingot form after melting at pressures in the range 10^{-5} to 10^{-2} mm. Hg.

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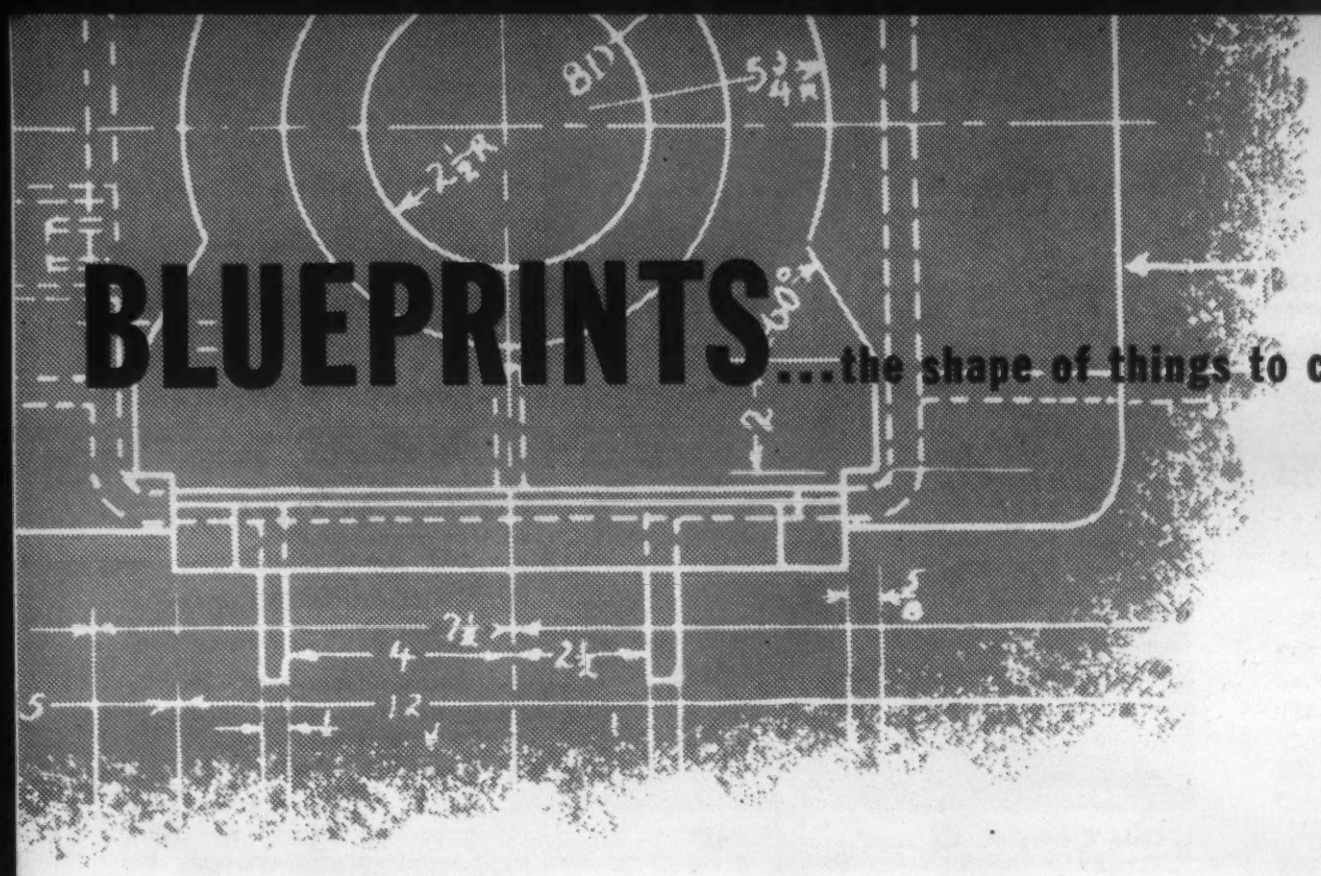

BLUEPRINTS...the shape of things to come

Triple Alloy Lighter Than Water

An alloy of three metals, lighter than water, yet fairly strong, is reported from England. Two of the metals, silver and magnesium, are heavier than water, but the third metal, lithium, is lighter than water and makes the triple alloy the same.

Magnesium in Place of Cast Iron

One can look for quite a movement in replacing certain cast iron parts with magnesium. In many cases the working properties of "mag" are at least equivalent to gray iron. Besides, it is lighter and iron castings are exceedingly scarce.

Stainless Steel Stabilizer

Columbium is plainly in the ascendancy over titanium as a stabilizer of stainless steel, at least judged by tonnages used and number of metallurgists employing it. Trouble is, the Belgian Congo does not supply enough at times, though Moscow reports finding a new deposit in the middle Ural Mountains.

Aluminum Automobile Bodies

One trouble with making all-aluminum automobile bodies in mass production is that aluminum alloys will not stand the severe deep drawing of steel bodies. So, the theory is, instead of making in one piece as in steel, make in several pieces and assemble. A spot welding technique has by now been worked out allowing for the successful joining of several stamped sections out of aluminum.

Nail or Screw? Both!

A half nail, half screw, that has the easy drive of a nail, but annular grooves that give the holding powers of a screw, has been found out to be practical. Boatbuilders especially are exploring its possibilities. Besides its design novelty, it is made of Monel.

Steel Conservation

Look for more intelligent use of steel and less scrap. What was once thrown back into open-hearths because of smallness or irregularity of contour will be used as a prime material. The Dodge plant of Chrysler stitches together odd shapes of scrap in a spot welding fixture and uses it in such integral body parts as end frames, engine dust pans and fender guards. Shaped edges of steel, trimmed from fender blanks, are rolled flat and reformed into seat edge frames and seat back frames. Dodge saves 300 tons of steel weekly and uses a higher quality of steel in these minor parts than they would otherwise.

Tin-Zinc Alloy Applications

A two-metal alloy, already called by some the most satisfactory finish for the steel chassis of radio sets, bids fair to spread to other applications soon. The alloy is of tin and zinc and may be applied to steel wire for fencing, netting and flyscreen.

Nickel Substitute in Radio Tubes

A metal substitute for nickel in radio tube electrodes has been developed by the Germans and found cheap and desirable for some applications. It is an alloy of aluminum and iron and is essentially an oxygen-containing iron sheet, plated on both sides with silicon-containing aluminum layers, about 0.010-mm. thick. Its surface changes from aluminum brightness to a dark gray color when vacuum heated at 1110 F. The metal has been used abroad for several years.

Contact Arc Welding

A new type of welding electrode, developed in Holland, may prove popular here. It combines the properties of touch welding, self starting and reignition, the technique being called "contact arc welding". The very heavy conductive coating of the electrodes was obtained by transferring a great part of the iron from the core wire to the coating, this iron being deposited in the weld. A greater reliability of the welded joint is obtained.

New Solder for Vacuum Tubes

A new alloy with good possibilities as a solder for vacuum tube construction, with a melting range of 1740 to 1815 F, is 37.5% gold and 62.5% copper, war-time experiments having been conducted by a leading electrical house. Twenty vacuum joints, including copper to steel, copper to fernico, and copper to copper, were made without leaks or mechanical failures. The high melting point is intermediate between that of copper and silver-copper eutectic. In certain cases seals are mechanically stronger than ones of pure gold.

Corrosion Inhibitor for Aluminum

Expect a new process that protects aluminum and its alloys against the equivalent of standard salt spray for 250 hr. It works only on noncopper bearing aluminum alloys, and consists of immersion in a dilute solution of salts at 210 F for 2 to 15 min. No electric current is used.

Fiber Glass vs. Goat Skins

Before the war goat skins from the high peaks of the Himalaya Mountains were considered sensitive and durable enough for diaphragms used in control and instrumentation in industrial processes. Fiber glass is now found superior to goat skins—it is nonporous, does not sag or stretch, is impervious to gases, has high resistance to alkalis and acids, and has longer life.

Recovered Waste from Pickle Liquor

Up to now there is much waste in pickle liquor of steel plants, but some of the products bid fair to having practical use. Iron sulphate has replaced gypsum as a setting-time regulator in portland cement at pilot plants. Practicability seems likely of making black iron oxide and ammonium sulphate from pickle liquor. Where stainless steel is pickled, studies for recovering chromium and nickel are under progress.

Correction of a "Correction"

Drops of perspiration from embarrassment blot this page as once again we try to get across the correct amount of tin to use on steel as pre-treatment before painting. The correct version, so help us, is ½ lb. to 2 lb. per 436 sq. ft. of surface to be treated. Since we muffed the facts in previous issues, we have learned that likely applications for this treatment are motor car bodies, steel window frames, refrigerators, water heaters, steel furniture, etc.